No 34

ELECTRONICS

The Maplin Magazine

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OCT-NOV '89 · £1.00

Nicam 728 digital stereo sound from your TV set. Start of a project showing you how to convert your TV.

Tips on taking measurements of distortion in the home laboratory.

MIDI thru' box for you to construct and use in your MIDI music system.

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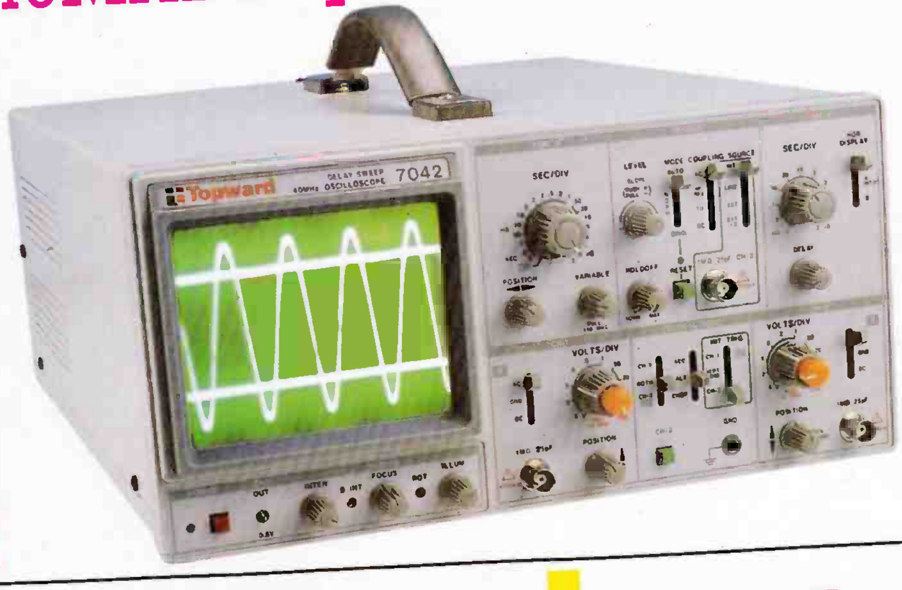

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OCTOBER TO NOVEMBER 1989 VOL.8 No.34

EDITORIAL

From early September the IBA will commence to broadcast programmes with digital stereo soundtracks, and 'Electronics' will be telling you all about how this works and presenting a series of projects which will enable you to listen to the stunning stereo sounds from your TV set via your own hi-fi system. Part one of the series starts in this issue, and gives an in-depth explanation of the capabilities of NICAM 728 and gives details of proposed launch dates for the service in the UK. Details are also given on how NICAM 728 will interface with satellite TV transmissions. Our thanks to Paul Gardiner of the IBA for this valuable information.

Also in this issue we present an ideal 'family' project in the form of an electronic dice, once constructed it will give hours of fun to the children (and mum and dad). Just think, no more hunting under the settee for lost dice! For musical buffs there is a superb MIDI thru' box for use with MIDI equipment and for dabblers in car electronics there is a useful remote power switch project. Plus, of course, the continuations of our regular serials, surely makes 'Electronics' a 'darn good read'! Read on and enjoy!

R.T. Smith

Editor Roy Smith **Technical Editors** Dave Goodman, Chris Barlow, Gavin Cheesman.
Technical Author Robert Ball.
Technical Artists John Dudley, Lesley Foster, Paul Evans.
Art Directors Peter Blackmore, Martin King.
Art Assistants Eugene Francis, Graham Smith, Danny Shadrake, Phillip Fey.
Print Co-ordinators Brian Lauezzari, Martin Needs.
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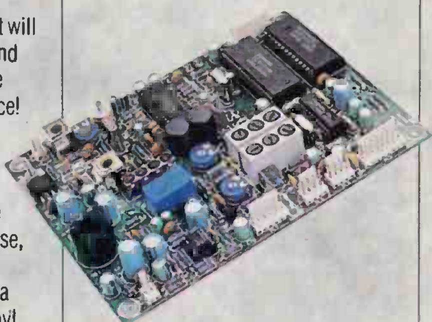
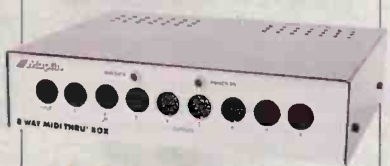
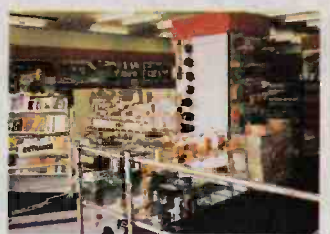
PROJECTS





FEATURES



REGULARS

CORRIGENDA

June to July 89, Vol.8 No.32
1) Page 18, Table 2. Tone System and Data Filter. The headings 'MARK' and 'SPACE' are transposed.
2) Page 18, 2nd column, line 8. 'When decoding an FSK signal the data output is 'high' or off state for the lower input frequency and 'low' or on state for the higher frequency.' Should read, 'When decoding and FSK signal the data output is 'high' or off state for the higher input and 'low' or on state for the lower frequency.'

August to September 89, Vol.8 No.33
Page 69, Parts List. Quantity for Trim Extrusion (FP03D) should be 8, Quantity for Castors pair (FX96E) should be 2. quantity for Recess Handle should be 2.

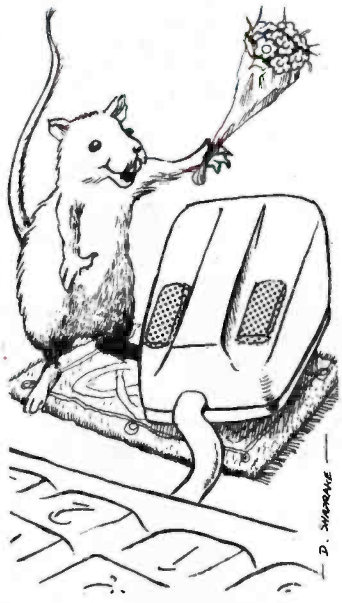
NEWS REPORT

Now that is Fast

IBM has made the world's fastest one-megabit dynamic memory chip. The experimental IBM Dynamic Random Access Memory – DRAM – can retrieve a unit or bit of information in just – wait for it – 22 billionths of a second. The chip can store the equivalent of about 100 pages of double spaced typewriter text.

According to IBM, high speed DRAMs, which are the most common type of memory chip used in computing, are in greater demand as mainframe computers and microprocessors have become more powerful and faster. Meanwhile, IBM has commenced production of the worlds' fastest one megabit DRAM chip manufactured in volume. The chip which operates at 65 billionths of a second will be used in the IBM AS/400.

Mouse Notes



Highlight of the 'News Report' must be the news that computer supplier INMAC have introduced a mouse mat available in a range of colours – mouse red, mouse blue and mouse grey. Further levels of mouse comfort is not being overlooked. The mat features a soft and resilient surface which is said to provide a base for good mouse performance. Should your mouse be feeling a trifle below par, then the company will supply some well proven mouse cleansing solution. When not in operation, INMAC provides a safe, secure and tidy mouse trap.

Further Mouse Footnotes

Talent Computer Systems report having developed a foot operated mouse which leaves available both hands to concentrate on the keyboard. The highly innovative product has apparently reached the finals of the Toshiba Year of Invention competition.

Sky Wars

Sky wars are hotting up. The up and running Sky Television organisation is doing its best to downgrade rival British Satellite Broadcasting. BSB who are making heavy weather of their 'squarial' type aerial, now hope to launch their 5 channel service early next year. Meanwhile the Sky management have not taken kindly to BSB government submission that News International who own Sky should divest its newspapers or its satellite television operation.

What appears to irk Sky in particular, is the fact that the government has granted BSB a host of special privileges including the right for their channels to be carried on all cable TV systems and to erect master aerials to serve apartment blocks without the need for a special licence.

For potential satellite subscribers, the problem remains – settle now for Sky or wait for the higher technical standards of BSB. Certainly Sky are losing no opportunity to convince viewers that they should make that choice option now. Last month saw Sky Movies broadcasting top films for sixteen hours a day. The remaining eight hours can be spent in watching one of the other Sky channels such as Sky News which broadcasts round the clock, Sky One or Eurosport.

In any case it looks like all parties will win the satellite wars. The latest growth figures from Frost and Sullivan suggest that by the end of the year, about 200,000 households in Western Europe will be equipped with antenna for receiving TV programmes direct from satellite. But this is just a start. By 1993, the report says European Households equipped with a dish aerial will total 9.37m.

Hard Times for Amstrad

Amstrad, the computer and hi-fi equipment supplier has come out fighting over the suggestion that thousands of Amstrad satellite dishes had been melting in the hot weather earlier this summer. The problem says the company, related to a very small number of minor plastic components which eroded under repeated exposure to ultraviolet rays. All is now well and a replaceable cap is available free of charge to all users.

Alan Sugar of Amstrad will be glad to see the back of 1989. No sooner had the satellite dish problems been sorted out than the company had to recall all its flagship hard disk PC 2286 and PC 2386 units to be refitted with a re-engineered hard disk controller circuit. Amstrad have certainly moved fast to reassure buyers, having probably learnt lessons from the earlier episode with the still best selling – and best value – PC 1512 when industry comment forced the company to fit what they believed to be 'unnecessary' cooling fans. Amstrad are also offering users of their business range of 2286 and 2386's, a free on-site maintenance service. If any reader has bought a 2286 or 2386, the Amstrad hot line number is 0926 429124.

Meanwhile, 'News Report' can reveal that Amstrad plans to reduce the prices of all its present computer range to a level which will 'stun' the market-place. More news next issue.

PC Growth Maintained

Last year, says Wharton Information Systems, the total spent in the UK on information technology topped £2 billion with over half a million PC units being installed. Other equipment high risers were facsimile machines, which were up by 200,000 bringing the installed base to over half a million – comfortably above that of telex machines. Strong sales have continued this year says Wharton with IBM, Compaq and Apple all reporting growth of around 50%. All this says the research company points to a buoyant software market. Other authorities meanwhile are pointing to robust growth in Expert Systems, portable telephones and Local Area Networks.

International Telephone Charge Card Launched

The House of Commons was the chosen venue for the world launch of an innovative international telephone charge card. The Executive TeleCard International, provides local toll free access to and from the UK and fifty two countries in Europe, America, the Middle and Far East and Australasia. Thanks to the new card, it would be possible for a British subscriber to phone from Paris to San Francisco and have the cost billed to his address in London. What is more, users can also take advantage of possible cheaper international tariff rates and outings. The clear advantage is of course that of avoiding the high hotel telephone surcharges. Most hotels add between 50 and 300% or more to the true phone bill. With the card, the hotel switchboard only recognises a local toll free call.

Details: Service 800. 01 938 2222.

Powerful PC from Philips

Philips are one of the first suppliers to announce a PC based on Intel's 33MHz 386 processor. The new P3370 machine has a system memory of 4MB as standard, expandable up to 8MB on the main board and via Intel 32-bit memory expansion cards, upto a maximum of 24MB. Equally impressive is the fixed disk capacity which ranges from 140MB up to 1280MB of on-line mass storage. Systems applications include high-capacity network file-serving and acting as a high performance personal workstation.

Details: 01 759 5000.

Stop the Junk Fax

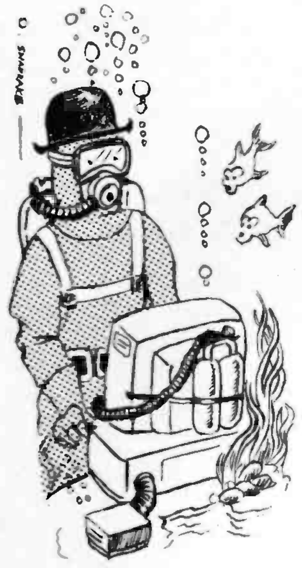
Canon's L920.

The growing problem of unsolicited facsimile messages which, unlike sales messages received by mail or telephone, actually cost the recipient money, is being urgently examined by the industry says leading accountants Sterlings of North London. Not only does the junk mail tie up the fax machine, it is printed out on the receivers own not inexpensive paper. To overcome the problem, one company has designed a software program which will only accept messages from pre-selected sources.

Meanwhile, later this year in certain American States, it will be illegal to send anyone an unsolicited fax message. But with penalties limited to just $200, the fine deterrent may not be sufficient to curb the practice. But more practical help is close to hand. Canon, the leading fax equipment supplier, has introduced an advanced machine which uses plain paper. Apart from cutting the cost of receiving faxes, the plain paper will overcome the problem of faxed documents fading in sunlight. At present the new facility is only available on a top end Cannon machine, the L920 Laser Fax, but Sterlings expect plain paper fax equipment to become standard issue within the next three years.

Details: Canon (UK). 01 773 3173.

A Computer for all Seasons



Once again the 'News Report' is indebted to that essential daily record of industry happenings, 'Computergram'. Apparently a US based company, Paranant Computer Systems, have manufactured an 'indestructible' laptop computer. This is not only waterproof (up to 15,000 feet), but can be left out in blazing sunshine or freezing ice. Just the job for the extrovert business traveller.

Video Moves

Come the 90s, it will not be a matter of "Do answer that phone" but more likely "See who that is on the phone". Videophones, long promised or threatened now look closer to becoming reality thanks to digital ISDN. The ability to be able to hear and see your caller, who can similarly see and hear you, has been available in the research labs for some time. Certainly back in 1984, Japanese companies were revealing the latest state of the video phone art at the international telecoms show in Geneva. The system operates at 64Kbps, considerably less than the normal TV transmission rates.

Great if you want to see as well as hear Mary, but not so thrilling if you are phoning the boss to tell him you are not feeling too well, especially if you happen to be dressed for a spot of windsurfing.

At least the videophone will feature a somewhat larger screen than the latest video game player. Clearly designed for the commuter, the Nintendo portable entertainment system which costs about $90 and comes with a free games cartridge, features a 2.5 inch black and white screen.

Good Surveys

Two recent surveys from Frost and Sullivan confirm the buoyant electric component and PCN market-place. The fastest growing electrical connector is a fibre optic item with growth more than doubling between 1988 and 1993. In end user markets, the report notes that the automotive sector is clearly the star, thanks to the movement for ever more electronic content in cars.

Meanwhile the report notes telephone handsets in Europe may soon have printed circuit boards moulded into their cases during manufacture. This is a case of circuitry becoming literally indistinguishable from the product itself – a revolutionary idea in what is already a $2.7b European market. The UK is the second largest European PCB market, but well behind Germany, with national production amounting to £349m by 1992.

News Report Goes Out and About

The Museum of the Moving Image (MOMI) located close by the National Film theatre on London's South Bank, is a must for anyone with an interest in the historic and contemporary developments in photography, cinema and television. Of course, MOMI does highlight such cinema greats as Charlie Chaplin, Marilyn Monroe and James Dean, but there is a lot, lot more to see plus not a few technological buttons to press.

Items and demonstrations range from early optical experiments – MOMI probably has the worlds' finest collection of pioneering equipment – to computer created graphics. A visit to the MOMI control room is a must for all electronic freaks. Here you can see some 70 video-disk players, each of which provides fast random selection and rewind in a matter of two seconds. Video monitors also control the 27 cameras within the exhibition.

On arrival you can enter a time machine which in true 'back to the future' tradition, zaps from Chinese graphics some 2500 years ago, to todays Dr. Who and Spitting Image. Visitors can enter a replica 1930's Odeon, complete with early Movietone News, inspect film and TV sets and rub shoulders with all the best characters Disney has produced. Even 'ET' would feel at home.

Innovative is perhaps the best word for MOMI. Even the attendants are 'resting' actors. A visit should not be too long delayed.

Liberalisation Moves On

It did not take the government long to award the first licence to operate the new digital mobile personal communications network (PCNs). Mercury has picked up the challenge to operate what the DTI describe as being a network pitched between cellular and Telepoint services. Meanwhile BT is feeling somewhat disgruntled being ineligible to bid for the new network. The new service will make use of the spectrum in the 1.7 – 2.3GHz range, which is currently reserved for military use.

At the same time, the DTI have freed European CB enthusiasts from UK licence needs. The 26.960 – 27.410MHz band known as the 'CEPT' channels has been established as a common CB radio service in most European countries. CB sets used within the UK by European CBers will need to be marked by manufacturers to show that the equipment has been approved in the users' own country. Of major significance to the UK network operators, is the relaxation of the rules which will allow companies to resell any spare capacity on their leased line private telephone networks.

The main effect will be to give wide freedom for the use of private circuits which are leased from BT or Mercury. Industry commentator Michael Naughton of ANR says the measures open the way for private network operators to compete with domestic carriers BT and Mercury in a wide variety of service markets.

And finally, in a little noticed move, the DTI has imposed a requirement on lift operators to provide inductive couplers in emergency phones in lifts – certainly a welcome boost for hearing aid wearers.

BT Connections

This year, apart from the French revolution anniversary, sees the 100th Anniversary of the Strowger telephone exchange. It is a well established fact that it was in 1898 that a Kansas City undertaker Almon Strowger patented the idea for automatic switching. He was as BT reminds us, spurred on to invent the system after discovering the telephone operator was married to his business rival and was connecting potential customers to him.

But BT report that their all talking, singing and dancing exchange is just around the corner – though the singing could turn to growling if you are not careful. The new BT digital system will send a polite message to remind you to replace your handset. If this polite request fails, it resorts to transmitting a 'howler' – a screech which will alert you even if you happen to be at the bottom of the garden.

British Telecom are busily defending their steady removal of the familiar red telephone boxes. The new tough, easy clean booths, with clear telephone keypads, make life a touch easier for thousands who would not or could not previously use a public telephone. As a final reassurance, BT have found the solution for improving its London directory enquiry service. Two hundred new operators are being recruited in Northern Ireland who will use high speed computer technology to handle millions of calls switched to the province. Apparently London directory enquiries are already being answered at centres in Yeovil, Torquay, Darlington and Durham as well as in the capital itself. Mind you, they will not be short of work. As Michael Naughton of Applied Network Research consultancy notes, the world telephone population is increasing by 5% every year, with already an estimated 700m numbered lines. North America says Michael Naughton is at the top of the league in terms of phones per population – one telephone for every two people, compared with Africa where the score is one per hundred.

The Worm Grows Up

Panasonic have added new models to their WORM Optical Disk Drive line up, which together with their popular LF-5200 (200MB/400MB) drive provides the ideal solution for the majority of users. The new drive is reckoned to be the highest capacity, highest performance and lowest cost per megabyte 5¼ inch WORM drive currently available in the market.

With an immense storage capacity of 940Mbytes on a double sided disk, the LF-5010E is ideal for the storage of archive data for applications such as desktop publishing and CAD/CAM, where the storage of test, images and drawings can take up hundreds of Kbytes.

This new drive also has more than twice the performance of the LF-5200, itself amongst the fastest currently available, with an average access time of 98msec and maximum sustained transfer rate of 655Kbytes per second. In practice this allows the drive to be used for on-line data storage with no noticeable difference in performance between it and a typical hard disk. This gives the user the important benefits of being immune to viruses, magnetic fields and head crashes, so there is absolutely no chance of the data being erased or corrupted.

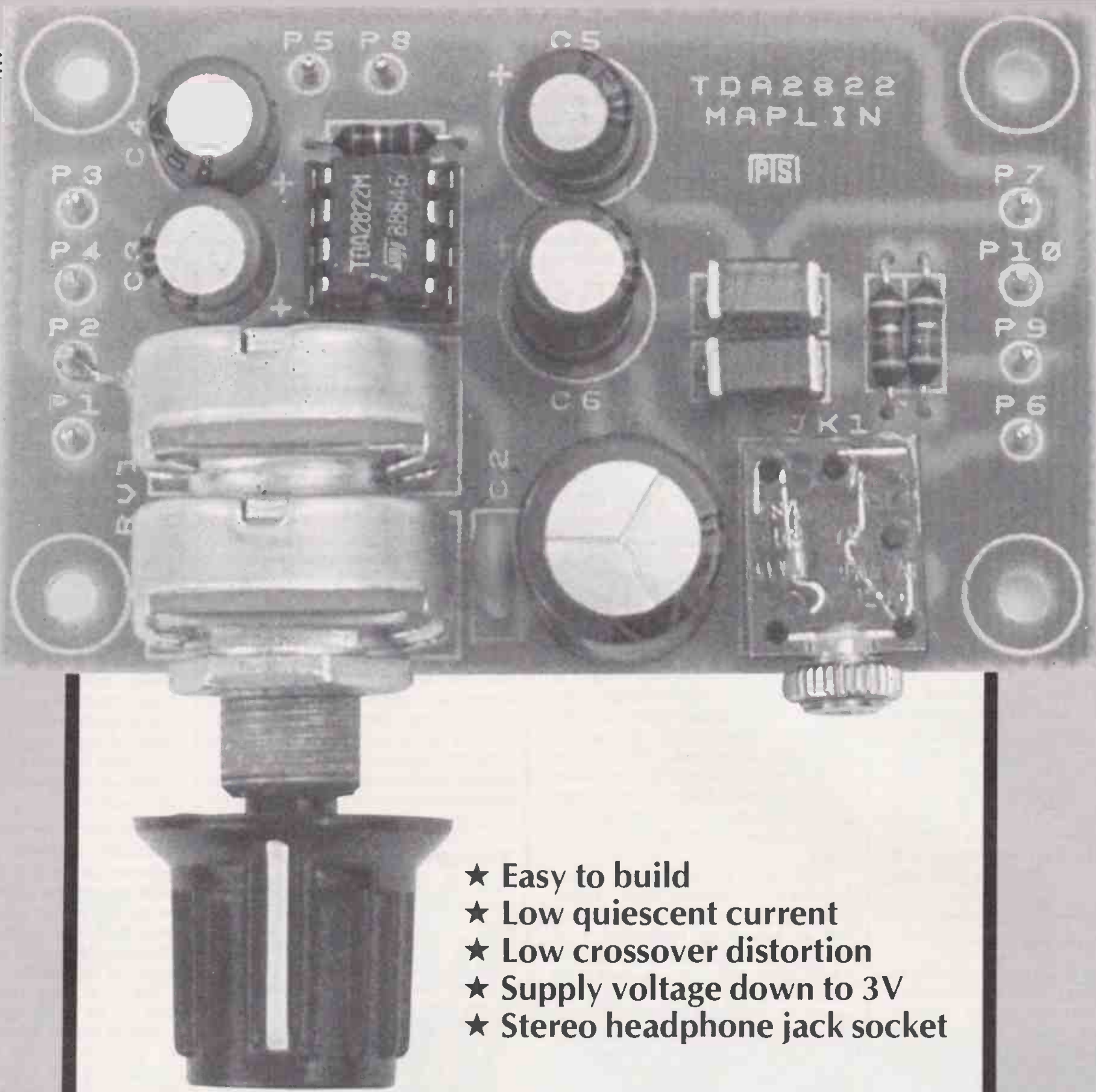
The LF-5010E is available to the end user at an RRP from £2750 as a complete plug-in and play subsystem for use with IBM PC XT/AT, PS/2 or compatibles and Apple Mac. In addition, the drive is available to the system's integrator or OEM in the industry standard 5¼ inch form, with embedded SCSI-2 interface (the LF-5012); plug-in and play kits are also available.

For users of the existing LF-5200 drive, fully upwards compatibility has been maintained, and existing 200MB/400MB disks are completely read/write compatible with the new drive.

Disks will be multi-sourced and available at £80 for single sided (470 Mbytes) and £135 for double sided (940 Mbytes).

Details: Panasonic. 0344 853334.

The LF-5010E.



- ★ Easy to build
- ★ Low quiescent current
- ★ Low crossover distortion
- ★ Supply voltage down to 3V
- ★ Stereo headphone jack socket

Specifications of Prototype

Test conditions:	PSU = 9V Output load = 8Ω
Input sensitivity:	26mV RMS
Input impedance:	47kΩ at 1kHz
Quiescent current:	8mA
Maximum volume (stereo):	260mA
Output power (each channel):	650mW RMS
Power bandwidth:	40Hz to 150kHz (−3dB)
Distortion:	0.9% THD
Output noise:	40μV RMS

TDA2822M
STEREO AMPLIFIER

by Chris Barlow

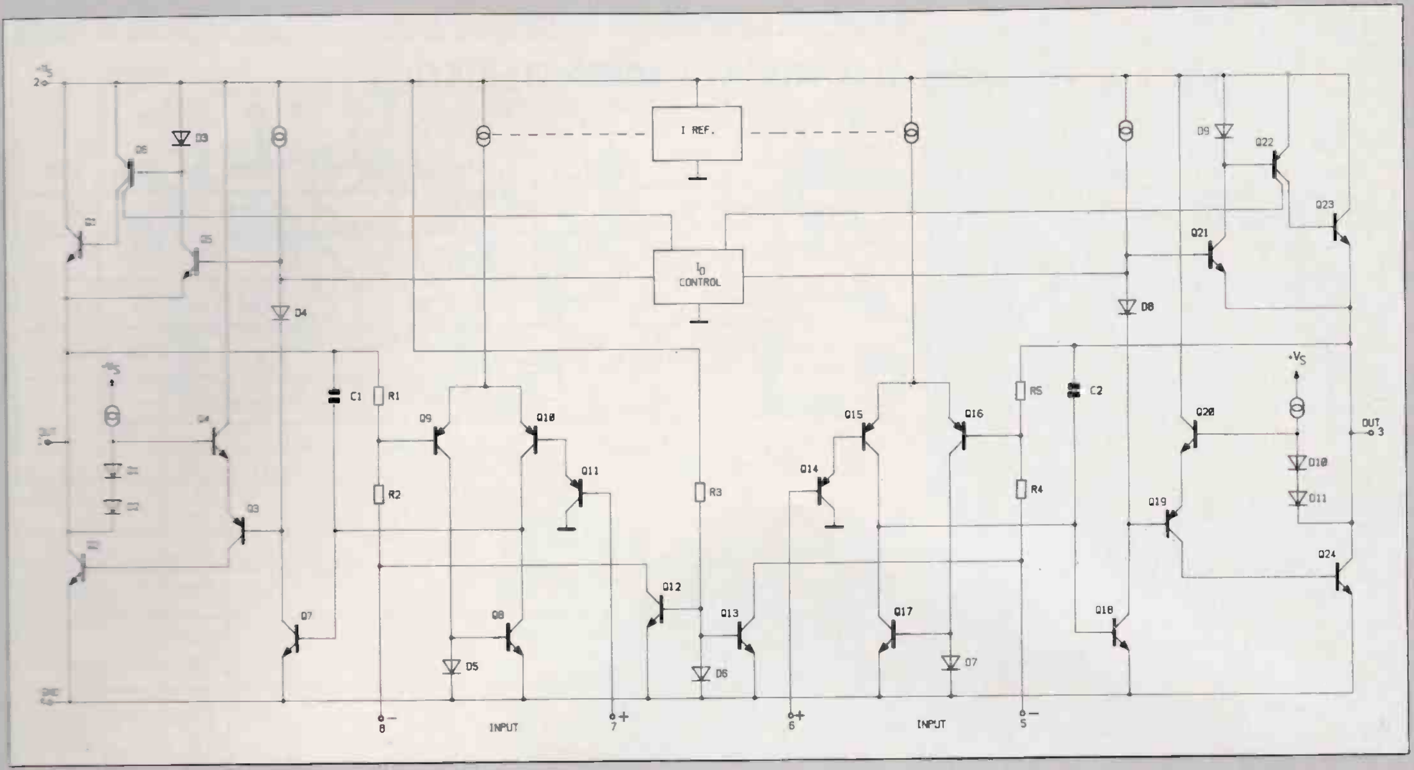


Figure 1. TDA2822M pin configuration.

The TDA2822M is a monolithic integrated circuit (IC) and with the rest of the components on the printed circuit board, it offers a small yet powerful stereo amplifier module. Because of its wide supply voltage range (3V to 15V) it is well suited for portable battery use.

As can be seen from Figure 1, the IC has only eight pins, which are assigned in the manner shown in Table 1.

The manufacturer of the IC has produced a series of response curves showing its electrical characteristics, see Figure 2. In addition, Table 2 lists the parameters, test conditions and expected results. The specification of the Maplin prototype gives a more practical set of results as it takes into account all the components in the completed circuit.

1 = Output one	(Left channel)
2 = DC supply voltage	(+3V to +15V)
3 = Output two	(Right channel)
4 = Ground	(0V)
5 = Inverting (−) input two	(Right channel)
6 = Non-inverting (+) input two	(Right channel)
7 = Non-inverting (+) input one	(Left channel)
8 = Inverting (−) input one	(Left channel)

Table 1. Pin assignments.

The Circuit

Only a few external components are required to provide the correct working environment for the TDA2822M, see Figure 3. The DC supply entering the unit on P5 and P8 must have the correct polarity, otherwise damage may occur to IC1. Electrical noise on the supply rail is suppressed by the decoupling capacitors, C1,C2 and resistor R3.

The left and right input signals are applied to P1 and P3, which are connected to the top end of RV1a and RV1b. This control is used to set the

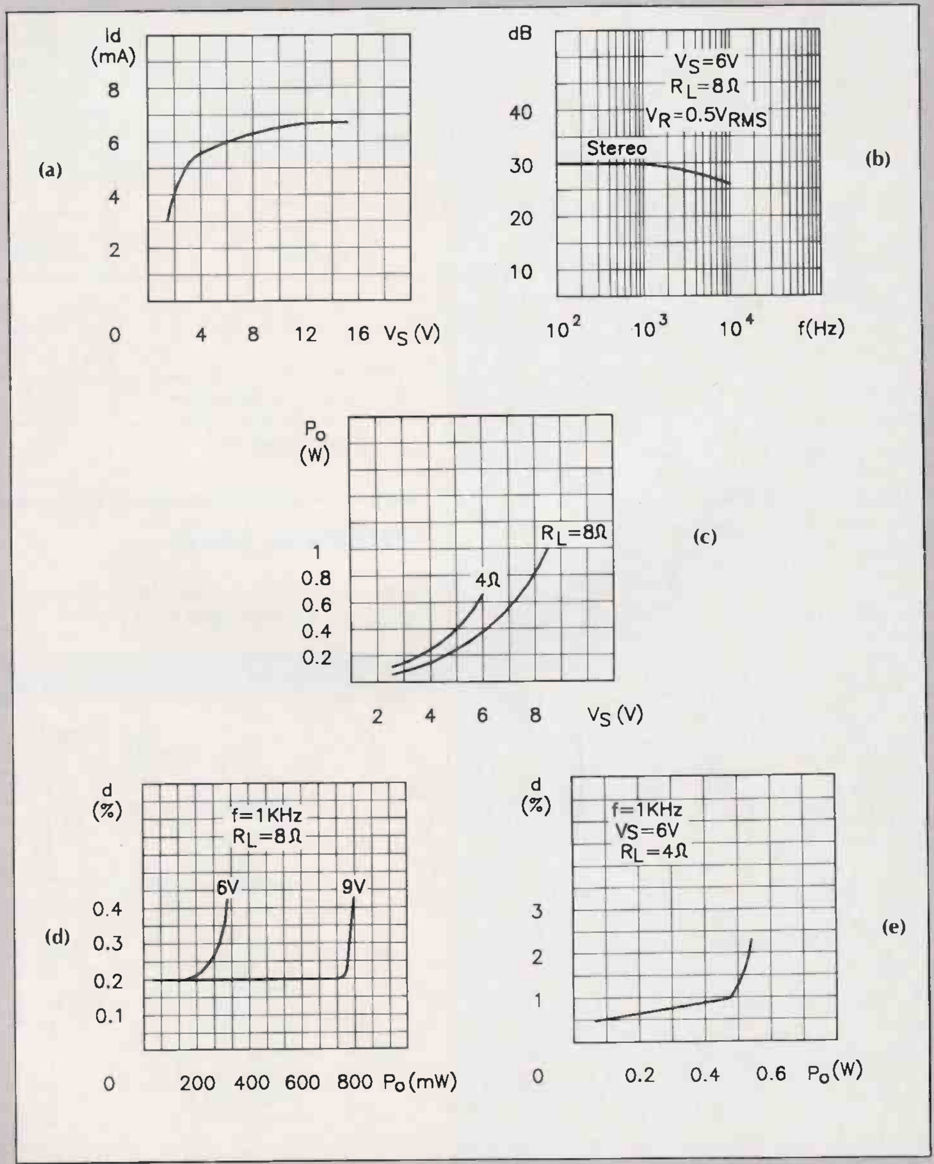


Figure 2. Electrical characteristics. (a) Quiescent current vs Supply voltage. (b) Supply voltage rejection vs Frequency. (c) Output power vs Supply voltage (THD = 10%, f = 1kHz stereo). (d) Distortion vs Output power (stereo). (e) Distortion vs Output power (stereo).

volume of the amplifier by tapping off the signal on its wiper which is connected to the non-inverting inputs of IC1 (pins 6 and 7). The inverting inputs of IC1 (pins 5 and 8) are AC grounded by C3 and C4.

The signal outputs of IC1 (pins 1 and 3) have a DC potential, so two blocking capacitors, C5 and C6, are used to feed the loudspeakers or headphones, with two Zobel networks comprising of C7, R1 and C8, R2 connected to the 0V ground. A PCB mounting 3.5mm stereo jack socket, JK1, is used to switch out the speakers when the headphones are inserted. The left channel speaker is connected to P6 and P9, while the right speaker connects to P7 and P10.

PCB Assembly

The PCB is a single-sided fibre glass type and has a printed legend to assist you in correctly positioning each item, see Figure 4. Removal of a misplaced component is quite difficult, so please double-check each component type, value and its polarity where appropriate, before soldering! The sequence in which the components are fitted is not critical. However, it is easier to start with the smaller components. When installing the electrolytic capacitors the positive lead must go to the plus sign (+) on the legend. However, on some capacitors the polarity is designated by a negative symbol (−), in which case the lead nearest this symbol goes away from the positive sign on the legend. When fitting the IC socket ensure that you match the notch with the block on the legend. Next install IC1 making certain that all the pins go into the socket and the pin one marker is at the notched end. Install the pins at the 'P' connection points P1 to P10 ensuring that you push them fully into the board. When fitting the volume control RV1 and the headphone socket JK1, make certain that they are pushed down firmly on to the surface of the PCB. Additional input screening can be implemented by grounding the metal body of the volume control, see Photo 1.

This completes the assembly of the PCB and you should now check your work very carefully, making sure that all the solder joints are sound. It is also very important that the solder side of the circuit board does not have any trimmed component leads standing proud by more than 3mm, as this may result in a short circuit. Further information on soldering and assembly techniques can be found in the 'Constructors Guide' included in the kit.

Wiring

Carefully follow the wiring shown in Figure 5. The stereo input cable must be the screened type (XR15R) and no more than three metres in length. The power supply and loudspeaker connections can be made using different coloured hook-up wires.

Testing

All the tests can be made with an

ELECTRICAL CHARACTERISTICS

(V_s = 6V, T_{amb} = 25°C, unless otherwise specified)

	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
V_s	Supply voltage			1.8		15	V
V_o	Quiescent output voltage				2.7		V
		V_s = 3V			1.2		V
I_d	Quiescent drain current				6	9	mA
I_b	Input bias current				100		nA
P_o	Output power (each channel) (f = 1kHz, d = 10%)	R_L = 32Ω	V_s = 9V		300		mW
			V_s = 6V	90	120		mW
			V_s = 4.5V		60		mW
			V_s = 3V	15	20		mW
			V_s = 2V		5		mW
		R_L = 16Ω	V_s = 6V	170	220		mW
		R_L = 8Ω	V_s = 9V		1000		mW
			V_s = 6V	300	380		mW
		R_L = 4Ω	V_s = 6V	450	650		mW
			V_s = 4.5V		320		mW
			V_s = 3V		110		mW
d	Distortion (f = 1kHz)	R_L = 32Ω	P_o = 40mW		0.2		%
		R_L = 16Ω	P_o = 75mW		0.2		%
		R_L = 8Ω	P_o = 150mW		0.2		%
G_v	Closed loop voltage gain	f = 1kHz		36	39	41	dB
ΔG_v	Channel balance					±1	dB
R_i	Input resistance	f = 1kHz		100			kΩ
e_N	Total input noise	R_s = 10kΩ	B = Curve A		2		μV
			B = 22Hz to kHz		2.5		μV
SVR	Supply voltage rejection	f = 100Hz	C1 = C2 = 100μF	24	30		dB
C_s	Channel separation	f = 1kHz			50		dB

THERMAL DATA

$R_{thj-amb}$	Thermal resistance junction-ambient	max	100	°C/W
$R_{thj-case}$	Thermal resistance junction-pin (4)	max	70	°C/W

Table 2. TDA2822M specification.

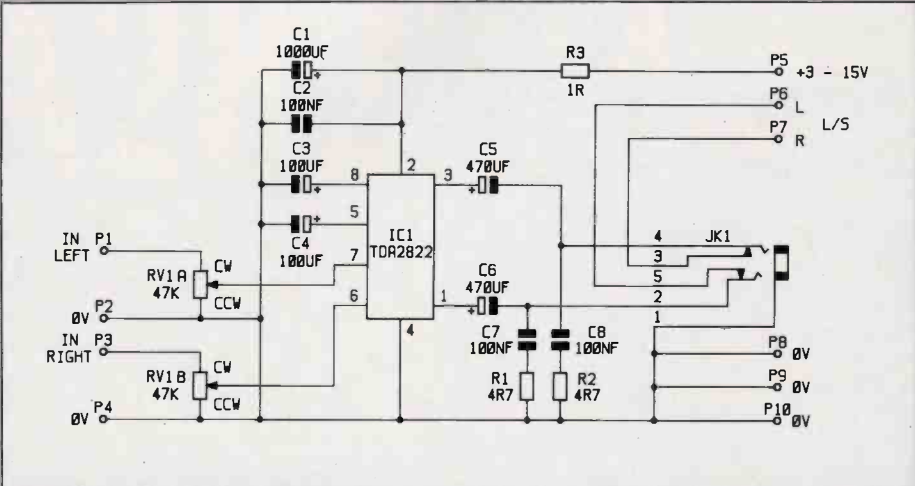


Figure 3. Circuit diagram.

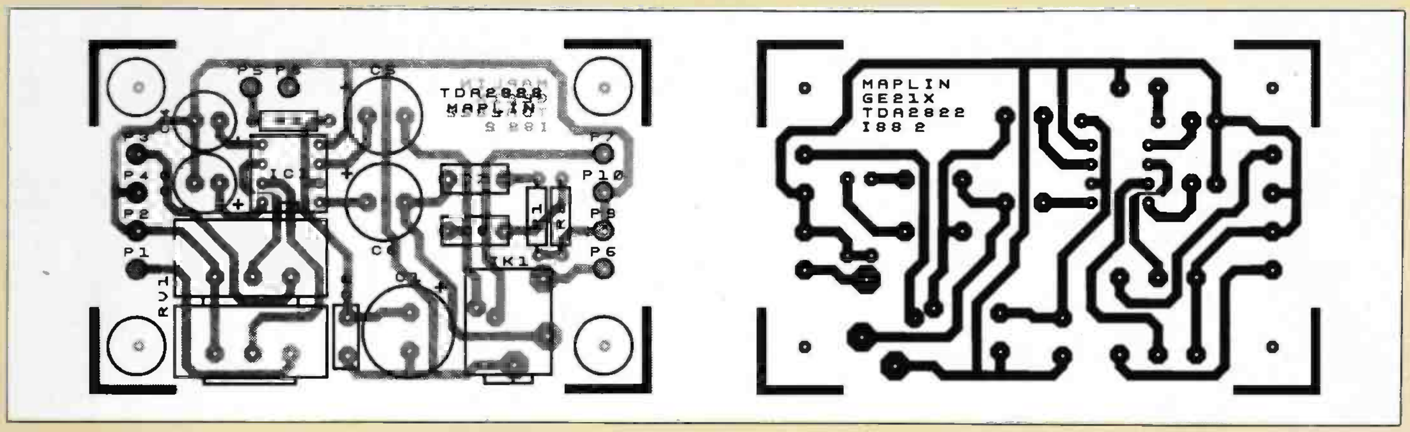


Figure 4. PCB track and legend.

electronic digital, or analogue moving coil, multimeter. The following test results were obtained from the prototype using a digital multimeter and a 9V power supply unit.

The first test is to ensure that there are no short circuits before you connect the power supply. Set your meter to read OHMS on its resistance range and connect the probes to P5 and P8. The reading obtained with the probes either way round should be greater than 500Ω.

Set the volume control to the fully anticlockwise position (minimum volume). Next monitor the supply current; set your meter to read DC mA and place it

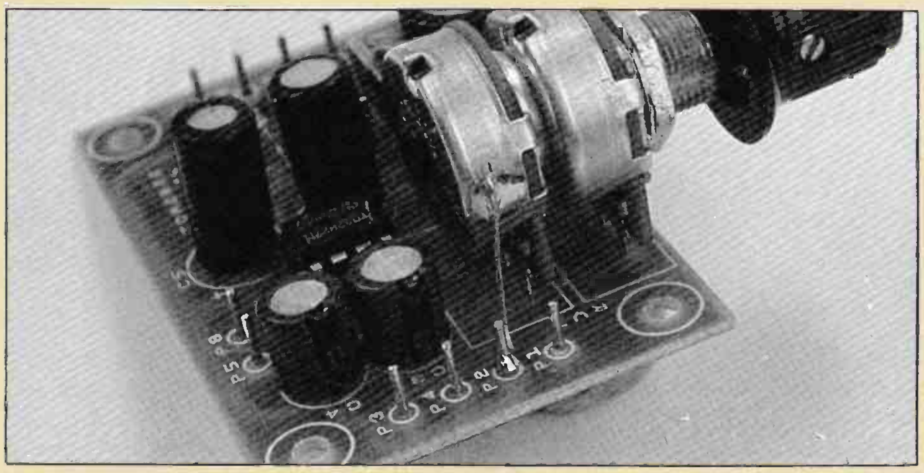


Photo 1. Earthing the case of RV1.

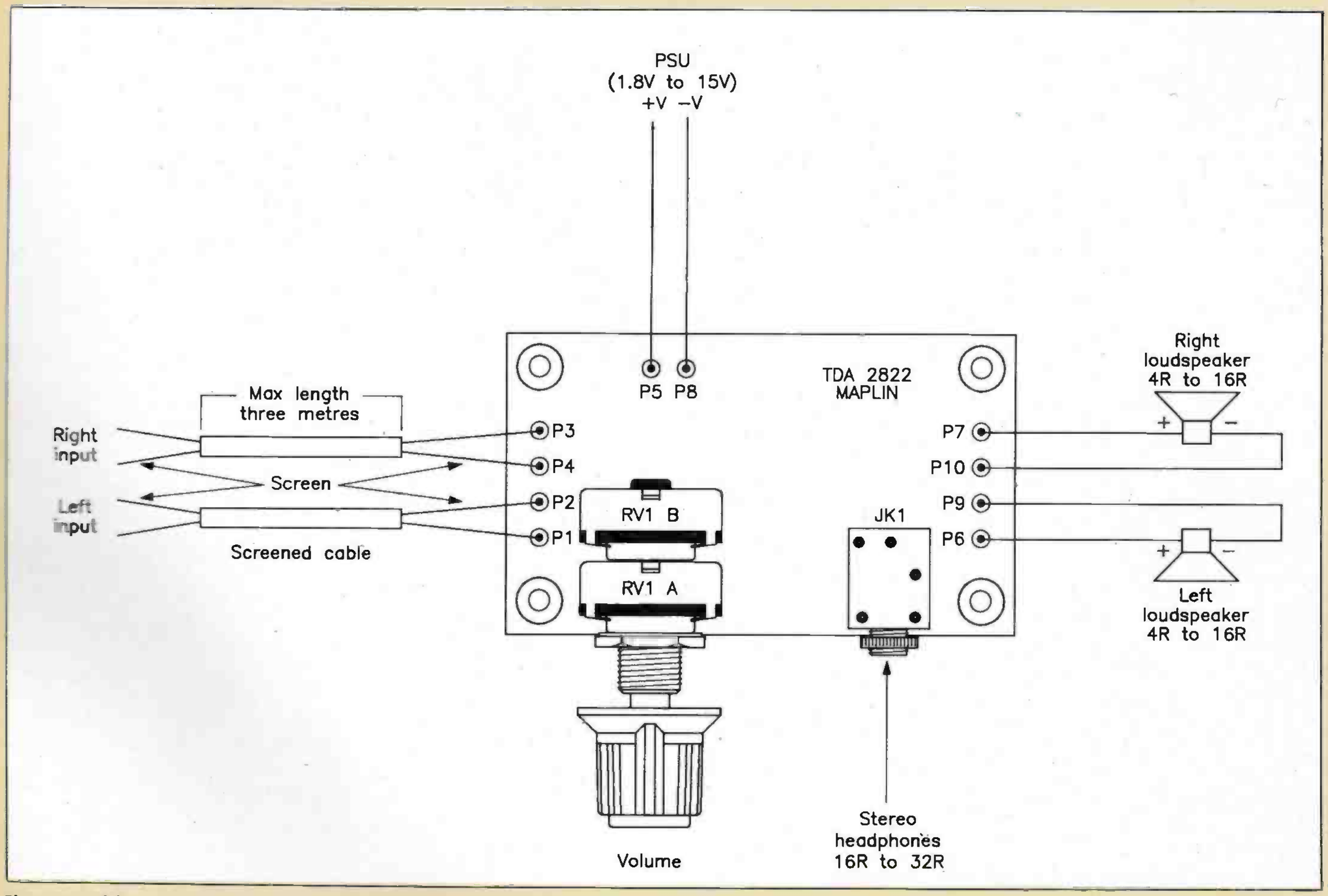


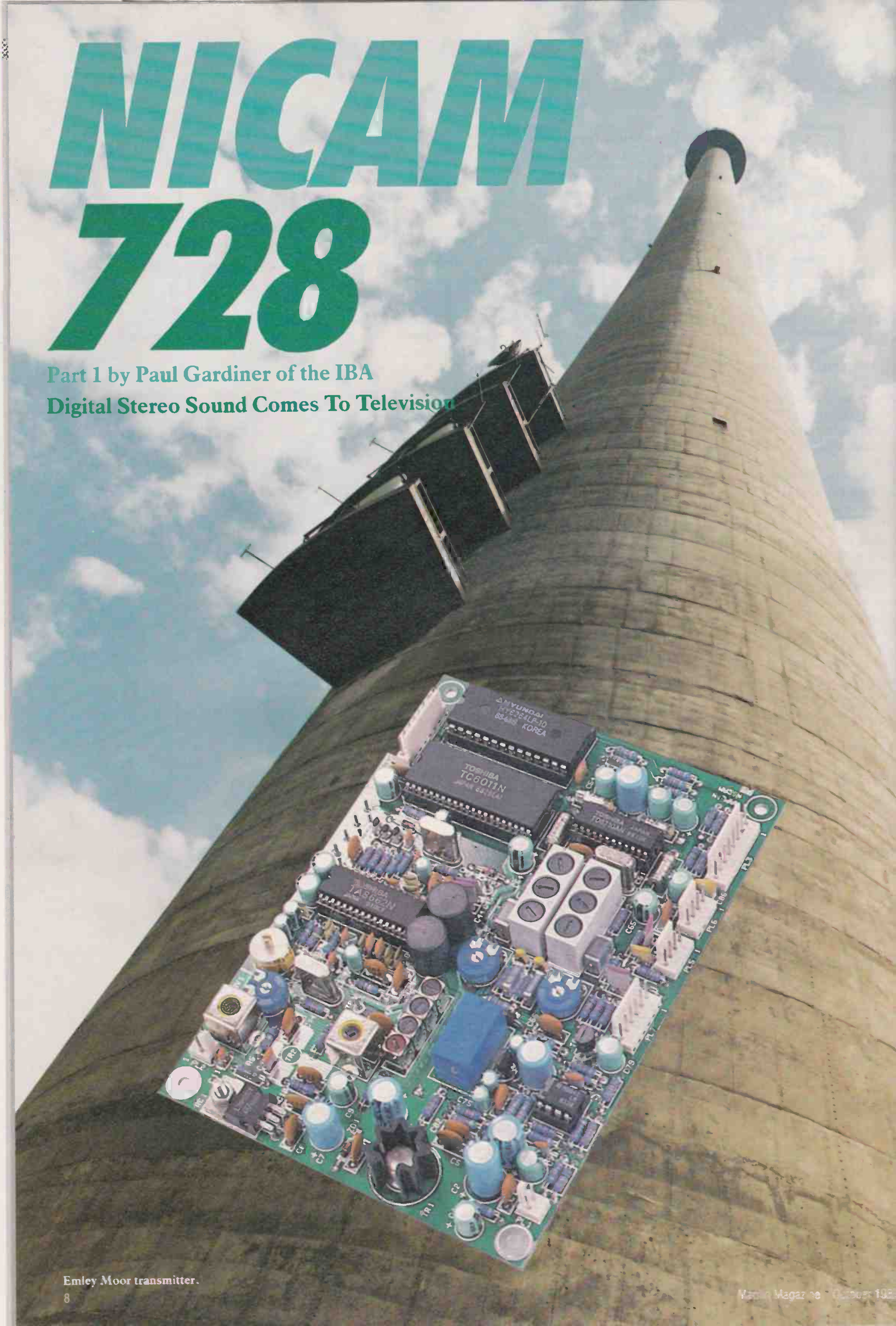
Figure 5. Wiring.

Contined on page 50.

NICAM 728

Part 1 by Paul Gardiner of the IBA

Digital Stereo Sound Comes To Television



Emley Moor transmitter.

Regular broadcasting of high-quality digital stereo sound on television is about to become a reality, starting on 11th September in London and parts of Yorkshire, on both ITV and Channel 4. Initially, there could be up to about two hours of stereo programming a day. The IBA will be extending the service to other areas during 1990, reaching 75% of the population by end-1990.

In the early 1980s there was considerable interest both in the UK and in Europe in the idea of adding dual-channel sound to television, either for multi-language sound, or for stereo. Various analogue schemes were considered, but it became clear that a digital system would offer considerably improved quality. The BBC carried out intensive development work and testing of a proposed new digital system, joined in the latter stages by the IBA (much of whose resources had been devoted to the development of the MAC/packet specification for the DBS).

This led to a joint BBC/IBA/BREMA specification of a system know as NICAM 728. This is now approved by the Department of Trade and Industry as the UK standard for two-channel digital sound with television on the terrestrial networks. Although originally designed for UK television System I, there has also been considerable interest overseas. Extensive tests have proved the ruggedness and compatibility of NICAM 728, which adds a low-level digitally modulated carrier to the existing vision and frequency-modulated sound signals.

NICAM was originally devised by the BBC in the late 1970s, with the aim of conveying sound programmes on digital circuits designed for multi-channel telephony. NICAM is an acronym for Near-Instantaneously Companded Audio Multiplex, and is essentially a digital bit-rate reduction system designed for high-quality sound. 'Companding' is a compression process applied to the audio signal prior to transmission, followed by an equal and opposite expansion process in the receiver. 728 refers to the digital bit-rate of 728kbit/s.

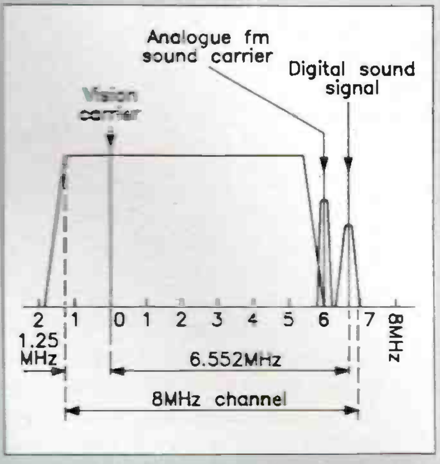


Figure 1. The frequency spectrum occupied by the NICAM 728 digital sound signal in relation to the vision and FM sound signals (UK System I). (Vertical axis not to scale.)

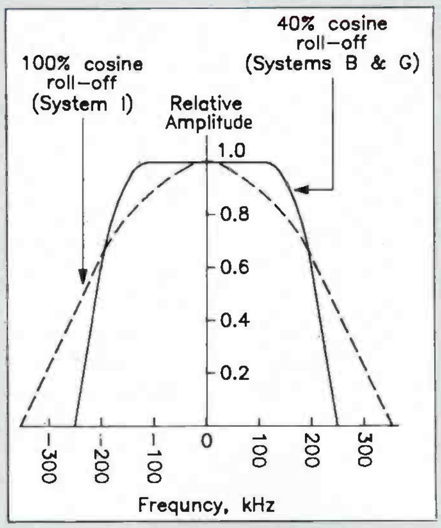


Figure 2. Spectrum shaping (due to combined transmit/receive data-shaping) for System I and Systems B and G.

The new carrier is spaced 6.552MHz (in the case of UK System I) from the vision carrier (see Figure 1) and conveys data at a rate of 728kbit/s. The conventional analogue FM carrier remains unchanged on 5.996MHz. However, the digital signal is at a much lower level, just 1% of peak vision power, compared to 10% for the analogue sound. The level of the digitally modulated carrier was chosen very carefully; a sufficiently high level to ensure rugged reception, while at the same time it is at a sufficiently low level to avoid interference to pictures or sound on existing receivers. The same applies to the choice of the frequency of the digital carrier in relation to the vision carrier, to avoid interference between the analogue mono FM carrier, and signals on the upper adjacent channel.

Prior to modulation, the bit-stream carrying the companded audio samples is scrambled in order to ensure that the transmitted signal appears as noise-like as possible, irrespective of content, so as to minimise the likelihood of interference to the analogue FM or picture signals. This is achieved synchronously with the frame structure by the modulo-two addition of a pseudo-random sequence.

A method of modulation known as differentially encoded quadrature phase shift keying (DQPSK) is used, also sometimes referred to as four-phase differentially encoded phase shift keying (4-phase DPSK). This makes very efficient use of the transmission bandwidth, while allowing reliable reception with a simple demodulator. The overall bandwidth in the case of System I is about 700kHz (see Figure 2). The same data spectrum shaping is applied both at the transmitter and the receiver, giving 100% cosine roll-off (for System I) for the overall data-channel spectrum.

DQPSK is a four-state phase modulation system in which each phase change conveys two bits (see Figure 3). The four rest-states are 90° apart; phase changes are caused from input bit-pairs as shown in Table 1. The input data stream at the modulator is differentially encoded by first forming bit-pairs by a serial to two-bit parallel converter. The entire process of differential encoding, data-signal spectrum shaping and modulation at the transmitter is illustrated in Figure 4.

Start of Transmissions

In the UK, the BBC have announced their intention to introduce NICAM digital stereo from seven main transmitters (and their relays) reaching 70% of the population in Autumn 1991.

The IBA began trade test transmissions from the Crystal Palace and Emley Moor main transmitters in March 1989 in order to gain some operational experience prior to the launch of a full service, as well as giving dealers the opportunity to demonstrate receivers. A preliminary service in London and much of Yorkshire is due to start on the 11th September, and is hoped to include up to two hours of stereo programming per day on both ITV and

Input bit-pair A_n	B_n	Amount by which the carrier changes phase
0	0	0° (i.e. no change)
0	1	−90°
1	0	−270°
1	1	−180°

Table 1. Relationship between the input bit-pairs and the changes of phase of the transmitted carrier.

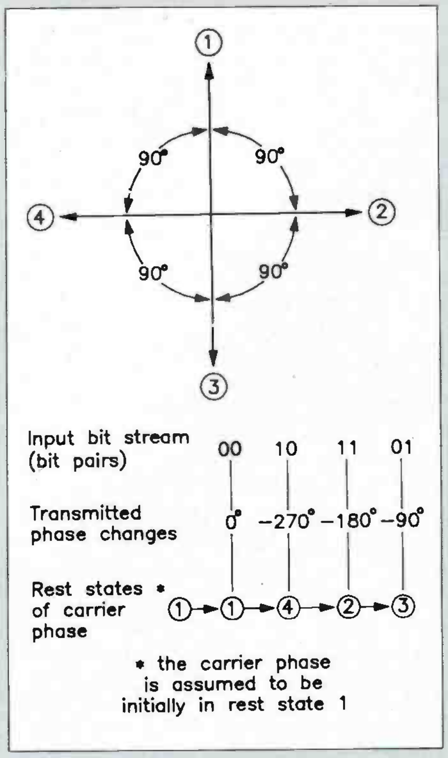


Figure 3. The four rest-states of carrier phase of the digitally modulated carrier for NICAM 728 are 90° apart.

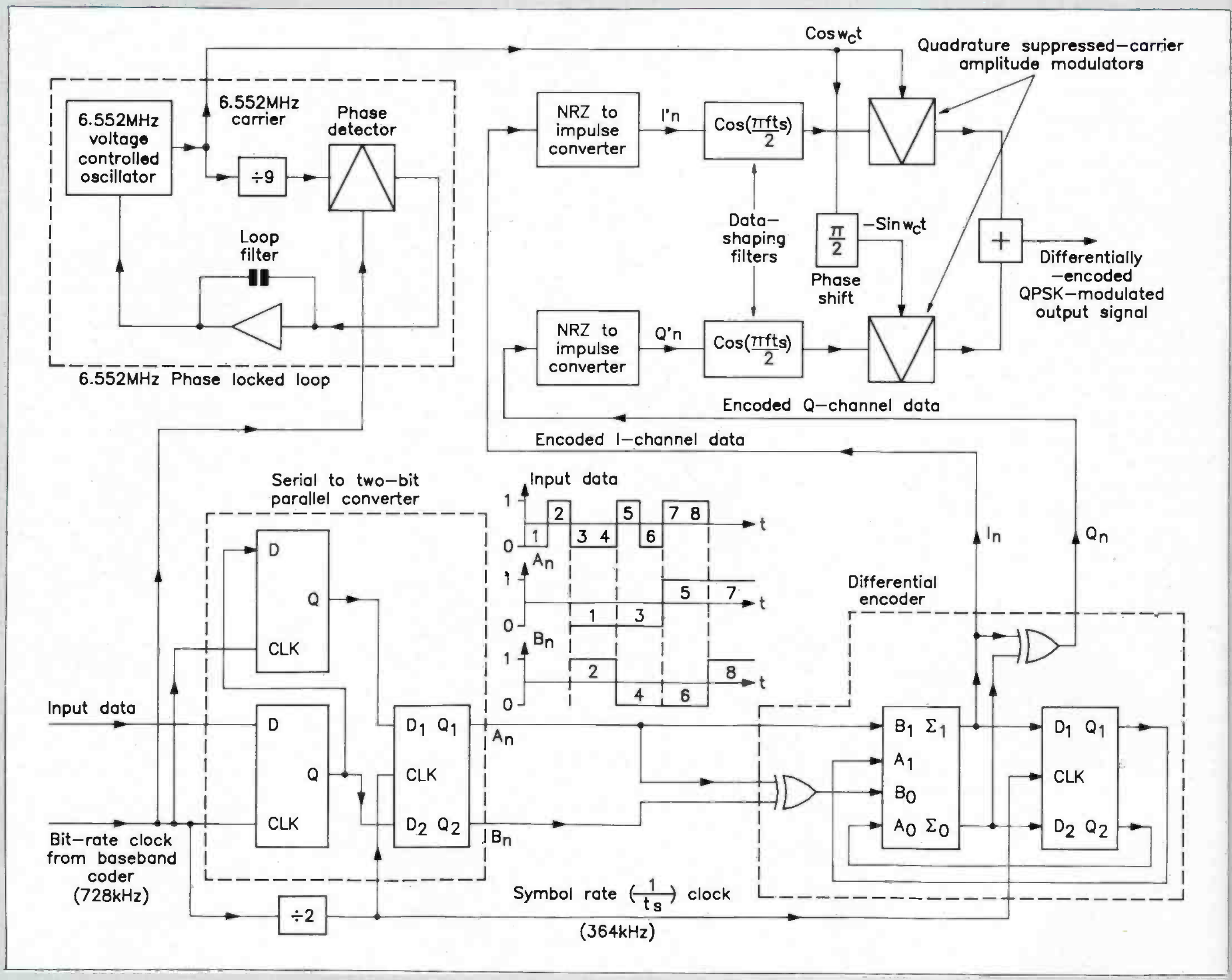


Figure 4. NICAM 728: Block diagram showing the processes of differential encoding, data-signal shaping and modulation at the transmitter.

Channel 4. This will be extended to other areas of the country from April 1990, reaching 75% of the UK by the end of 1990 (see Table 2). Complete UK coverage depends upon progress of subsequent phases of the IBA's current re-engineering programme, but could be achieved by about the mid-1990s.

For both ITV and Channel 4, it was initially intended that the additional digital dual-channel facility be used to provide stereo, rather than additional separate mono sound channels (possibly in another language), which could in theory be provided instead. The existing analogue mono sound will continue to be transmitted, but will be derived at the transmitter from the incoming digital stereo signals.

The distribution networks for both ITV and Channel 4 will be equipped with dual-channel sound-in-sync equipment, dispensing with the separate analogue sound circuits that are at present used on ITV. The existing mono sound-in-sync equipment for distribution of the fourth channel will also be replaced by dual-channel equipment. The IBA expects the dual-channel sound networking arrangements to be in place nationally in early 1990.

Station	Programme Co	Transmission Capability	Service Date
Crystal Palace	Thames/LWT	March 1989	11 September 1989
Emley Moor	Yorkshire	March 1989	11 September 1989
Wenvoe	HTV Wales	March 1990	April 1990
Winter Hill	Granada	April 1990	May 1990
Mendip	HTV West	April 1990	May 1990
Caradon Hill	TSW	May 1990	June 1990
Black Hill	STV	May 1990	June 1990
Durris	Grampian	June 990	July 1990
Divis	Ulster	July 1990	August 1990
Sandy Heath	Anglia	July 1990	August 1990
Caldbeck	Border	August 1990	September 1990
Pontop Pike	Tyne Tees	September 1990	October 1990
Rowridge*	TVS South		Autumn 1990
Dover*	TVS South-East		Autumn 1990
Sutton Coldfield	Central	October 1990	November 1990
Bilsdale	Tyne Tees	November 1990	Decemeber 1990
Belmont*	YTV		Autumn 1990

*These stations are being *modified* for NICAM digital stereo operation and there is some flexibility in timescales for the engineering work.

Table 2. Provisional dates for NICAM digital stereo from IBA transmitters (ITV and Channel 4/S4C). The service will also become available at the same time from each main station's respective relay transmitters.

Sound Coding

So how are the two audio channels coded prior to transmission? NICAM 728 conveys two high-quality audio signals, each with a bandwidth of 15kHz. The process of converting an analogue signal into digital form involves sampling the analogue signal at a rate of at least twice the highest frequency, and in this case a sampling rate of 32kHz is used. The initial coding accuracy is 14 bits per sample. If few bits were to be used, the quantising error could become audible in the form of a 'gritty' quality for low-level signals, an effect known as granular distortion.

However, the use of 32kHz sampling with a 14 bits per sample (i.e. 'linear' coding) would imply a transmission data rate (including parity bits for error detection and correction) approaching 1Mbit/s for stereo. This rate is rather too high to be accommodated easily in the form of a digitally modulated subcarrier with the 8MHz channels of System I, so a form of bit-rate reduction is used.

Near-instantaneous digital companding enables the number of bits per sample to be reduced from 14 to 10 for transmission, but with virtually no perceptible degradation in sound quality. This enables the basic bit rate for two sound channels to be reduced to about 640kbit/s. To this must be added certain overheads needed to ensure reliable transmission, including framing words, parity bits, and control information associated with the companding process. The end result is a 728kbit/s data signal.

Near-Instantaneous Companding

Analogue audio companding systems have the objective of improving the signal-to-noise ratio; the expander characteristic in the decoder has to be matched very accurately to that of the compressor in the coder in order to minimise audible distortion in the form of 'pumping' effects. A digital companding system with the objective of reducing the data rate has the advantage that the coder and decoder can be matched precisely, avoiding any mis-tracking.

The companding technique is known as Near-Instantaneous companding, and is based on the NICAM-3 system developed by the BBC in the 1970s. Essentially, the analogue sound signals are first coded into digital form with an initial resolution of 14 bits per sample, and are then reduced to 10 bits per sample for transmission. However, for quiet audio passages the receiver is able to restore the original 14-bit samples. There is a loss of initial resolution only on high-amplitude signals.

The companding process operates by grouping successive audio samples (in 2s complement form) into blocks of 32 samples (i.e. a duration of 1 ms) and examining the largest sample in the block. The amplitude of this sample is then used to determine the way in which the entire block of 32 samples is treated as a group.

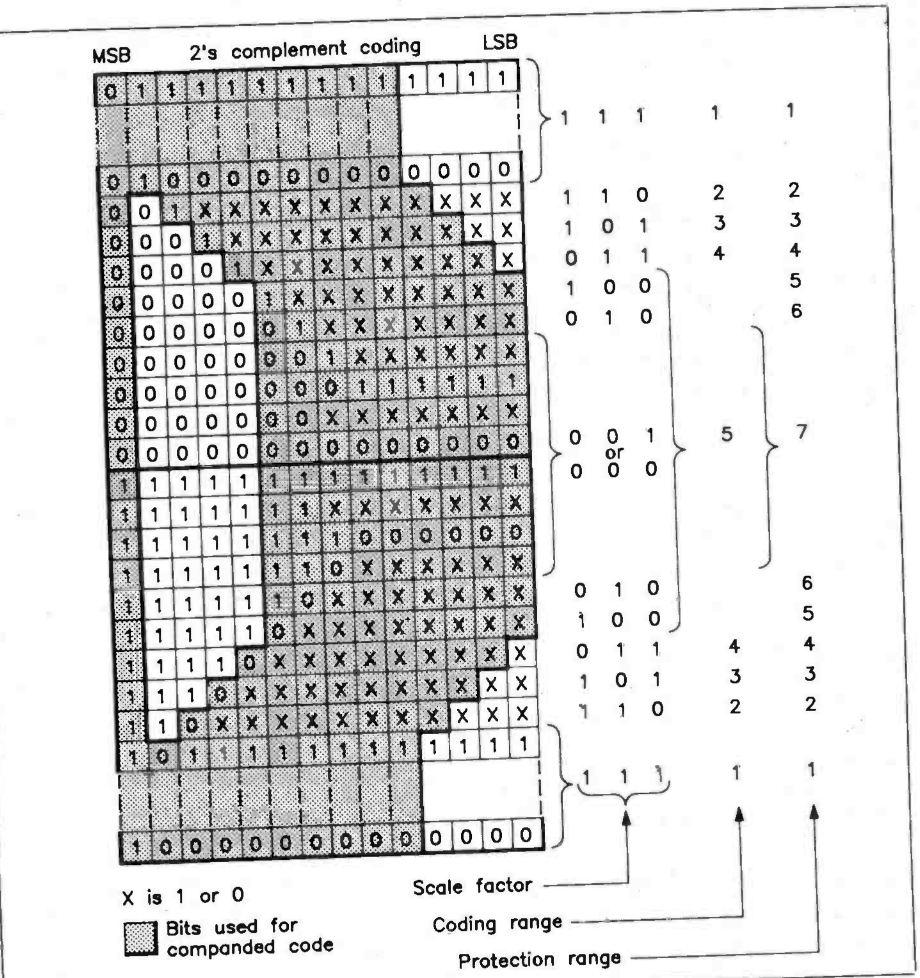


Figure 5. Coding of companded sound signals.

There are five coding ranges (see Figure 5); range 1 represents a block where the largest sample falls between maximum amplitude and half maximum amplitude; range 2 from half to quarter maximum amplitude, and so on. Range 5 represents one-sixteenth maximum amplitude down to silence.

The coding range used for each 1ms 32 sample block is signalled by a 3 bit scale factor word. For a block of samples representing signals in the largest amplitude range (coding range 1), the four least significant bits of each sample are simply discarded. In the case of blocks falling in the second coding range, the next-to-most significant bit of each sample is discarded along with the three least significant bits. (The most significant bit is always retained in order to indicate positive or negative signal excursions). However, because the 32 sample block is 'labelled' as falling

Application control information C_1	C_2	C_3*	Contents of 704-bit sound/data block
0	0	0	Stereo signal comprising alternative A-channel and B-channel samples
0	1	0	Two independent mono sound signals (designated M1 and M2) transmitted in alternate frames.
1	0	0	One mono signal and one 352kbit/s transparent data channel transmitted in alternate frames.
1	1	0	One 704kbit/s transparent data channel.

*$C_3 = 1$ provides for signalling additional sound or data coding options. When $C_3 = 1$, decoders not equipped for these additional options should provide no sound output.

Table 3. Application of the 704 bit sound/data blocks of NICAM 728 to provide either stereo sound, mono sound, transparent data, or a combination of mono sound and data.

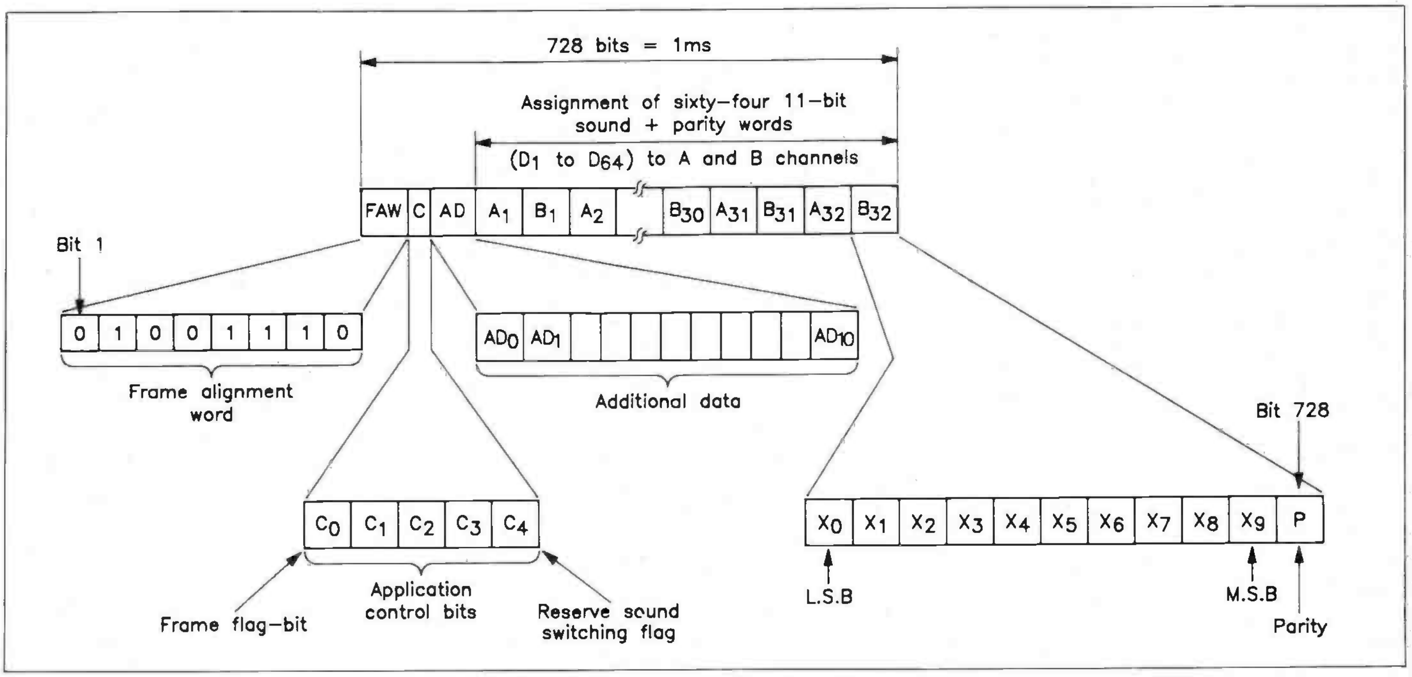


Figure 6. Structure of 728 bit frame containing stereo sound (before interleaving).

within coding range 2, the decoder can re-constitute the missing next-to-most significant bit, since this always has the same value as the most significant bit (Figure 5).

The effective resolution of the decoded signal for samples in range 2 is, therefore, 11 bits. In the third range the two least significant and two next-to-most significant bits are discarded prior to transmission, but the latter *two* bits are restored in the receiver (since they are identical to the most significant bit). The effective resolution is 12 bits. Similarly, lower amplitude signals in the fourth and fifth ranges are recovered in the decoder to 13 bit and 14 bit resolution respectively.

The companding process relies on the fact that the high-level signal itself masks programme-modulated noise. In order to further reduce the audibility of programme modulated noise, pre-emphasis to CCITT Recommendation J.17 is applied before compression, either by using an analogue pre-emphasis network prior to digitisation, or by using digital filters with the digital signals. A corresponding de-emphasis network is used in the receiver decoder following the expansion process.

Frame Structure: NICAM 728

The transmitted serial data stream is partitioned into 728 bit frames, transmitted continuously every 1ms; the overall bit-rate of 728kbit/s is made in the following way:

8 bit Frame Alignment Word:	8kbit/s
5 bits for Control Information:	5kbit/s
11 bits for 'Additional Data':	11kbit/s
704 bits for Sound and Parity:	704kbit/s
Total:	728kbit/s

It is this multiplex that is used to modulate the low-level carrier added to the conventional broadcast signal.

The 704 bit sound/data block consists of sixty four 11 bit sound samples (a single parity bit is added to each sample to protect the six most significant bits), made up of a coding block for each of the two sound channels. In the case of stereo sound, the 32 samples for each of the 'A' and 'B' channels within each sound/data block are interleaved (odd-numbered samples convey the 'A' channel, see Figure 6). If it is required to carry two independent mono sound channels, alternate frames convey data from each of the two audio channels (this is done in order to achieve compatibility with the packet coding structure for mono sound in the MAC/packet system). Alternatively, the system can provide a single mono sound channel and a separate data channel, or could even be devoted entirely to data transmission.

The first eight bits of each frame comprise a frame-alignment word (01001110) for receiver/decoder synchronisation. The first of the five Control Information bits that follow (the 'frame flag' bit C0) is set to 1 for eight successive frames, and to 0 for the next eight frames.

Coding Ranges	Protection Ranges	Scale Factor Value R_2	R_1	R_0
1st range	1st range	1	1	1
2nd range	2nd range	1	1	0
3rd range	3rd range	1	0	1
4th range	4th range	0	1	1
5th range	5th range	1	0	0
5th range	6th range	0	1	0
5th range	7th range	0	0	1
5th range	7th range*	0	0	0

Table 4. The coding and protection ranges associated with each 3 bit scale-factor word. The five coding ranges indicate the degree of compression to which the block of samples has been subjected for the near-instantaneous companding process.

The first frame (Frame 1) is defined as the first of the eight frames in which C0=1; the last frame (Frame 16) of the sequence is the last of the eight frames in which C0=0. This 16 frame sequence is used to synchronise changes in the type of information being carried in the data channel.

The next three bits (the 'application control' bits C1, C2 and C3) indicate the type of information being carried by the current 704 bit data block. Four possible applications have been defined: stereo sound, two independent mono sound signals, mono sound and separate 352kbit/s data channel, and a single 704kbit/s transparent data channel (see Table 3). In the case of the IBA transmissions, these bits will usually be set to 0, since for the time being it is planned to use NICAM 728 mainly for stereo sound. If it is required at any time to change the application, the forthcoming new application is signalled to the decoder by a change in the control bits on Frame 1 of the *last* 16 frame sequence of the current application.

The fifth control bit (the 'reserve sound switching flag', C4) lets the receiver/decoder know whether the conventional analogue FM subcarrier is carrying the same programme sound as the digital signal. When the FM signal is *not* carrying the same information as the digital stereo (or primary digital mono) sound signal, C4 should be set to 0. (Should there be two separate digital mono sound channels rather than stereo, C4 would relate to the content of the mono sound channel transmitted in odd-numbered frames.) A use of this control bit can be to prevent a receiver switching to different FM sound should there be a 'drop-out' in reception of the digital signal. However, this control bit should not be relied on for the automatic selection of television programme sound in the receiver; the broadcasters recommend that receivers should be switchable manually to select either FM or digital sound.

Use of the 11 bits of Additional Data (i.e. an 11kbit/s data signal) has not yet been defined.

Bit interleaving is applied to the 704 bit sound/data frame in order to minimise the effect of multiple bit-errors. This results in adjacent bits in the transmitted serial data stream being separated by a 16 bit interval, so that provided an error burst spans 15 or fewer bits, it will be spread as single bit-errors in the sound samples after de-interleaving in the decoder. Any errors affecting the six most significant bits of any sound sample will be detected by the parity check, and concealed. Errors in the least significant bits will not be detected but, should they occur, they tend not to be subjectively annoying to listeners. The decision to apply parity checking and error concealment to six MSBs was made after conducting various listening tests during the development of the MAC/packet system. If more bits are protected, then the effects of unconcealed errors in the least-significant bits become more disturbing.

Scale Factor Information

The decoder must know the appropriate 3 bit scale factor word used for each 32 bit sound-coding block, in order to reconstruct the audio samples correctly. Rather than use dedicated bits, this information is conveyed by using a technique known as 'signalling-in-parity'.

Two sound coding blocks are contained within each frame so that, for each frame, six scale factor bits must be transmitted. The way this works is to take a group of nine samples within a coding block, and to signal one bit of the scale-factor by allocating either even or odd parity to each sample of the group of nine. If it is required to signal a scale factor bit equal to 0, then the group of nine bits is allocated even parity; odd parity is used in order to signal 1. This form of signalling is effective because, under normal reception conditions, it is most unlikely that there will be several errors within each group of nine. The receiver checks each sample for parity in the normal way, and compares the results with the transmitted parity bits for each group of nine samples.

For those groups in which the majority of samples have odd rather than even parity, the scale-factor bit signalled by the group is taken to be a 1. Error concealment can then be applied to any samples in the group as necessary.

This method of 'signalling in parity' is very robust, since at least four samples in a group must be in error before a wrong decision on scale factor can be taken by the decoder.

The scale factor bits also provide a further form of protection against errors. In addition to signalling one of the five coding ranges, seven protection ranges are signalled (see Table 4). These allow the receiver to make certain deductions about the most-significant bits of the incoming samples of the group. For example, in protection range 6, the six MSBs should all be the same (Figure 5). This makes it possible to identify errors in the MSBs even if the parity check indicates that all is well (as a result of multiple bit-errors). Majority logic can then be used to correct these errors.

There is no protection range 8 in order to retain compatibility with NICAM in its application with the MAC/packet system. Scale factor 000 indicates protection range 7 (as does 001), but in the MAC/packet system this is used to manage receiver buffer storage of the data packets which make up the sound channel.

Satellite Broadcasting: MAC/packet

NICAM coding can also be used for satellite broadcasting (and cable distribution) using the MAC/packet standard. However, the method of transmission is quite different to that of terrestrial System I. There is no separate carrier; instead, the sound is carried in the packet multiplex associated with the MAC vision signal. This has a considerably higher capacity than the data signal of NICAM 728; about 1.5Mbit/s in the case of D2-MAC, and about 3Mbit/s for D-MAC (the UK standard for DBS). In other words, instead of offering two high-quality digital sound channels, D-MAC can offer up to eight.

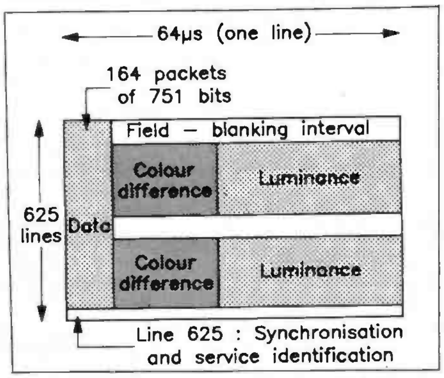


Figure 7. The structure of 625 line MAC/packet frame, showing the time-division relationship between digital data (at the rate of 20.25Mbit/s for D-MAC) and the vision signal. The data is structured in the form of packets containing 751 bits, carried at the rate of 4,100 packets per second.

The broadcast terrestrial television signal consists of a frequency multiplex of vision carrier, colour subcarrier, FM carrier and digital carrier. The MAC/packet format, however, comprises a time-division multiplex (see Figure 7). Digital data in duo-binary form is inserted into intervals between picture lines; in the case of D-MAC/packet at the rate of 20.25Mbit/s, and for D2-MAC/packet at 10.125Mbit/s.

The data is structured in the form of packets each containing 751 bits. Each packet contains a header which includes an address (used to identify the service to which the packet belongs), and a data area of 720 bits. A particular sound or data service is made up of many such packets, so that unlike the continuous transmission of sound/data frames for terrestrial NICAM 728, packets containing data for a particular sound channel are multiplexed with packets containing data related to other services.

The packet multiplex can be used to convey either medium-quality (7kHz bandwidth 'commentary' sound using 16kHz sampling) or high-quality (15kHz bandwidth, 32kHz sampling) using either 14 bit linear or 14-to-10 bit NICAM coding. In each case, there is the option of one or two levels of error protection. In the case of NICAM, the sound companding process is deliberately identical to that of terrestrial NICAM 728. However, periods of low-level sound (1/64th maximum amplitude or less) with a duration of at least 8ms are signalled to the receiver by a scale-factor value of 000. This allows for the management of the receiver buffer storage to obtain a smooth, regular output of sound samples since, as already mentioned, it is for the reason of this use of scale factor '000' that there is no 8th protection range in NICAM 728, both '001' and '000' are valid conditions in the 7th protection range in order to allow for the possibility of the transfer of sound between NICAM 728 and MAC/packet in digital form.

In the case of high quality stereo sound (using first-level protection) the 704 bits of data in a sound coding block are identical to that of NICAM 728 and can simply be accommodated within a single packet. The first sixteen bits of the 720 bit data area of the packet are not used. The use of a single parity bit to protect the six most-significant bits of each sample and 'signalling-in-parity' of the scale factor information are identical to that of the NICAM 728.

The MAC/packet specification also allows for an alternative higher level of protection for the sound, although it is not planned to use this for UK DBS. The flexibility of the packet multiplex does result in some extra complexity compared to NICAM 728; for example, there is an additional overhead in the form of sound control packets which contain 'Interpretation Blocks', sent between one and three times per second to ensure that the receiver has knowledge of the coding format of the sound channel.

The end result is that DBS, with programmes from British Satellite Broadcasting (BSB) planned to begin next spring, will offer the same high quality of digital stereo sound as terrestrial NICAM 728, with the further possibility of additional sound and data services.

NICAM 728: UHF Transmissions

Adding the 6.552MHz digital carrier does, in general, require some modifications to be made to existing main transmitting stations, particularly in modulation and IF processing, although not to relay stations which simply transpose between different UHF channels. Many main transmitters use separate high-power klystron amplifiers for the conventional FM sound signal. These operate with relatively high efficiency and narrow bandwidths.

The amplification of a second digital sound carrier requires more linear operation with a wider bandwidth, as well as the IF pre-correction of inter-modulation products. Other transmitters use common amplifiers for sound and vision signals; the inclusion of a third carrier will mean having to modify or replace existing circuits.

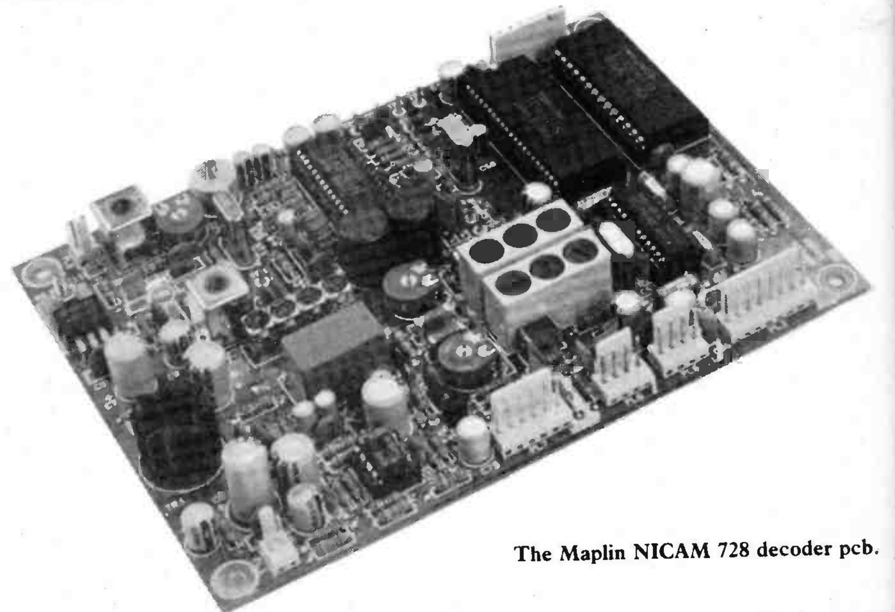
Further modification may be required to the sound/vision combining units. The IBA is currently modernising many of the early ITV main transmitter installations, and the new replacement equipment is specified to deal with the NICAM 728 carrier. However, modifications are being carried out to existing fourth-channel transmitters to enable them also to provide NICAM digital stereo.

The situation with relay stations is more straightforward, since the input-channel signals are converted first to an intermediate frequency and then to the new output channel without demodulation, in broadband form. In general, satisfactory performance is obtained without adjustment, even for chains of several relays operating in tandem. Any limitations will be due to the cumulative effects of intermodulation products causing visible patterning on the pictures, rather than any degradation of the digital sound.

Much of Europe uses television Systems B and G, rather than System I (used by UK and Eire). System B uses VHF channels with 7MHz channel-to-channel spacing, compared to 8MHz channels on UHF. To accommodate the 728kbit/s data signal in the narrower channel, a carrier at 5.85MHz above vision is used instead of 6.552MHz (see Figure 2). A change of data-shaping filtering at the source and receiver (40% cosine roll-off overall instead of 100%) is also required to prevent interference to the upper-adjacent vision channel.

In practice, reception of NICAM 728 has been found to be extremely rugged. Sound failure occurs only under very poor picture conditions, in the case of both weak-signal reception and in situations affected by severe multipath distortion.

As for the all important factor of sound quality – the results speak for themselves and compare very favourably with the compact disc.

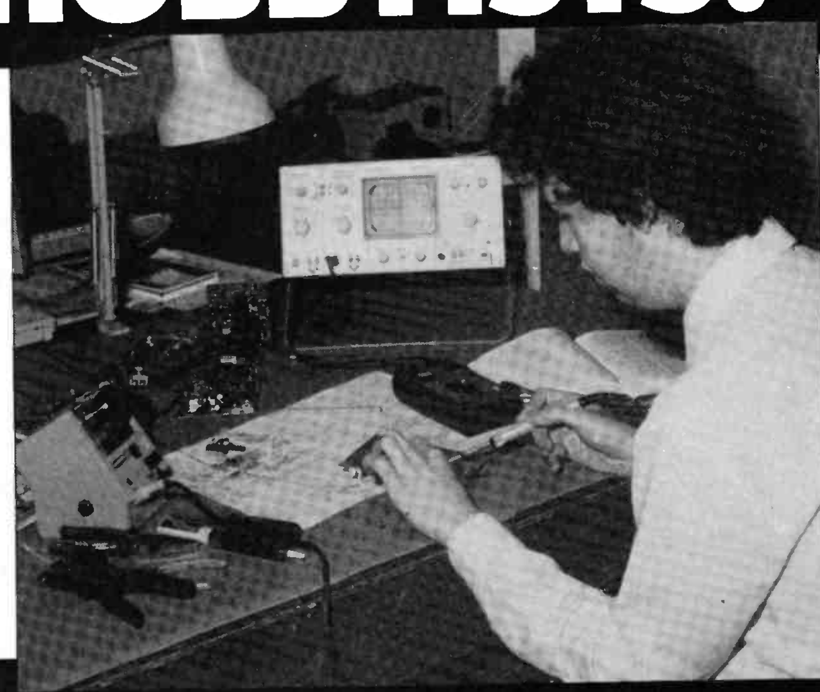


The Maplin NICAM 728 decoder pcb.

Next Time

In the second part of this series, full construction details will be given to enable you to build a NICAM 728 decoder board. This project will be available in kit form and will include the necessary NICAM chip set. So place an order for your copy of *'Electronics – The Maplin Magazine'* from your newsagents now! Just think, you could be the first in your street to hear beautiful stereo sounds from your TV.

Paul Gardiner is Principal Engineering Information Officer at the Independent Broadcasting Authority.



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Spectrum Anaylser.

Measuring *Distortion* in the Home Workshop

Part 1

by John Woodgate B.Sc.(Eng.), C.Eng., M.I.E.E., M.A.E.S., M. Inst. S.C.E.

What exactly is distortion?

The amount of distortion produced by a piece of audio equipment, especially an amplifier, is something of great interest. This is as it should be because we know that distortion affects the quality of sound that we hear, making it, at least, unpleasant to listen to and, in the case of speech subject to a large amount of distortion, impossible to understand. However, the frantic urge by amplifier designers for less and less distortion has been taken to ridiculous lengths. It is most unlikely that anyone's enjoyment of music, speech or any sort of programme material whatsoever has ever been spoiled if the distortion in the system was less than 0.1%, yet we see amplifier specifications claiming 0.005% or even less. Of course, amplifiers in test equipment (such as distortion meters!) may require such tight specifications. In large systems, such as broadcasting networks, where a signal may pass through many (low level) amplifiers in its journey from microphone to transmitter, the distortions of individual amplifiers tend to add (but occasionally cancel), so here, too, very low distortion may be essential.

Where does it come from?

Distortion occurs in every piece of equipment, from disc player (even CD) through to the loudspeaker (especially the loudspeaker!). While we shall be considering amplifiers in this article, because measuring distortion in other equipment is rather more difficult, most of the arguments and conclusions apply to all kinds of equipment.

Distortion occurs because the instantaneous output of the amplifier is not exactly proportional to the instantaneous input. If it were, the graph of instantaneous output against input (Figure 1a) would be a straight line, so the amplifier would be described as 'linear', and would produce no distortion. This graph is called the 'transfer characteristic', and its slope is the gain of the amplifier. The effect of a non-linear transfer characteristic is shown in Figure 1b. The degree of curvature shown is exaggerated: it represents an amplifier giving a great deal of distortion. You can see the effect on the output waveform produced by a sinusoidal input signal.

Strictly speaking, this is an example of one of two classes of distortion, and it is called 'non-linearity distortion' (often incorrectly rendered as 'non-linear distortion'), for obvious reasons. The other class is called 'linear distortion', and refers to frequency and/or phase response errors. 'Distortion' by itself normally means non-linearity distortion.

If there is no basic fault in the circuit design, the type of transfer characteristic shown in Figure 1b is caused by imperfections in the transistors or other active devices. For example, the current gain of a bipolar transistor is not precisely constant, but depends to some extent on the emitter current and the collector-to-emitter voltage, one or both of which must vary with the input signal if we are to get any output from our amplifier. More subtle effects can occur; the collector-to-base capacitance of a bipolar depends on the collector-to-base voltage, and if the load resistance is high enough, the frequency response of the stage will vary with signal level. This is particularly important if the stage in question is inside a negative feedback loop, because the open-loop gain will be made to vary with signal level, and the distortion in the output signal is nearly inversely proportional to the open-loop gain. This is an example of 'dynamic non-linearity', of which more later.

AM/FM Signal Generator

Photo courtesy Marconi Instruments

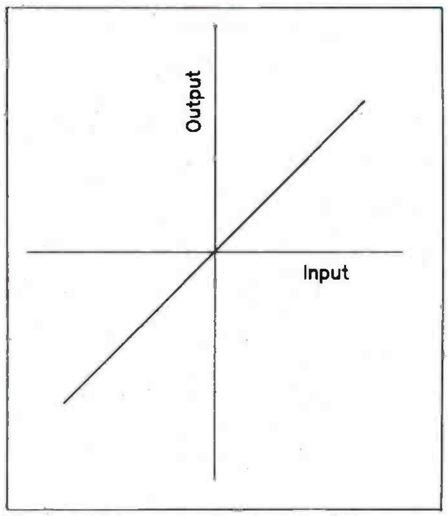


Figure 1a. Linear transfer characteristic.

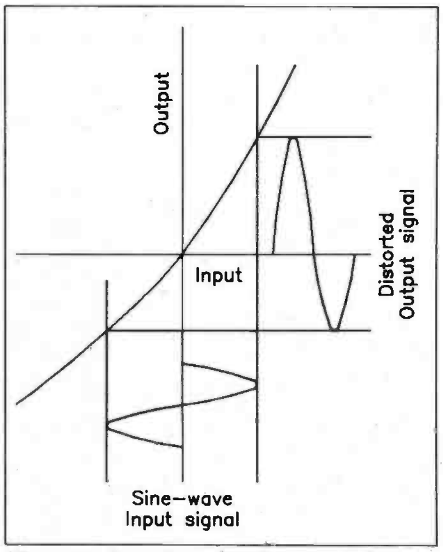


Figure 1b. Curved transfer characteristic showing distorted output from sine wave input.

Another type of distortion is shown in Figure 1c. Virtually all amplifiers, except certain special designs not used in audio, produce this form of distortion if the input signal is large enough. This is called 'peak clipping', or just 'clipping', and represents the onset of overload: the amplifier cannot deliver any more output. We usually consider 'voltage clipping', because it is easy to see that a transistor amplifying stage cannot produce an output voltage higher than its effective supply voltage, but amplifiers can run out of current, rather than voltage, and current clipping can be a much more subtle problem ('Effective' is meant to cover 'bootstrapping', which increases the effective supply voltage).

Different sorts of distortion

We can measure distortion in many ways, and we can express the results of such measurement in various different ways as well, so it is not surprising that there is great confusion on this subject. Since distortion comes from non-linearity of the transfer characteristic, the first thought might be to measure that. Unfortunately, this presents three major problems. A decent transfer characteristic is very, very nearly a straight line, and small measuring errors would make the results useless. We might be a bit more clever and measure the difference between what the output should be (which we can calculate; it is simply the input amplitude multiplied by the theoretically-constant gain) and what it actually is, which is called the 'transfer error characteristic (Figure 1d), but we then run into Snag Number Two. If we obtained Figure 1d as a graph of the results of a measurement, we would want to know if it represents good or bad performance. Unfortunately, it is almost impossible to tell; it depends in a complicated way on the exact shape of the error curve. Less error is obviously better than more error, but we can't go much further than that. A number of theoretical cases can be solved exactly, but this is not of much practical use. What is more, it is not too difficult to measure the transfer characteristic of a d.c. amplifier, but it is much more difficult if there is even one capacitive coupling or decoupling in the circuit. It looks easy: just apply a sawtooth or triangular wave input signal, attenuate the output by a factor equal to the amplifier gain, and subtract the result from the input signal. Try it, and see what a dog's breakfast phase-shift makes of the result! It is very difficult to correct phase-shift of a non-sinusoidal waveform precisely. This is Snag Number Three, and we have to look for some other approach.

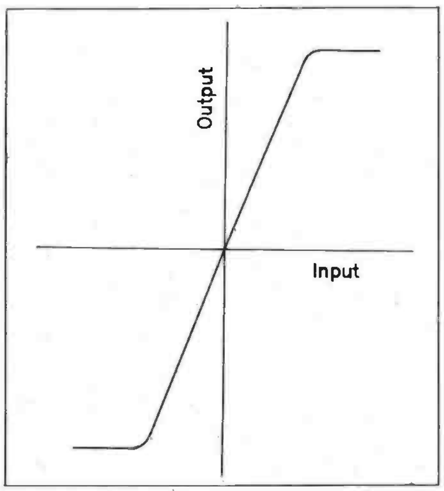


Figure 1c. Transfer characteristic showing peak clipping.

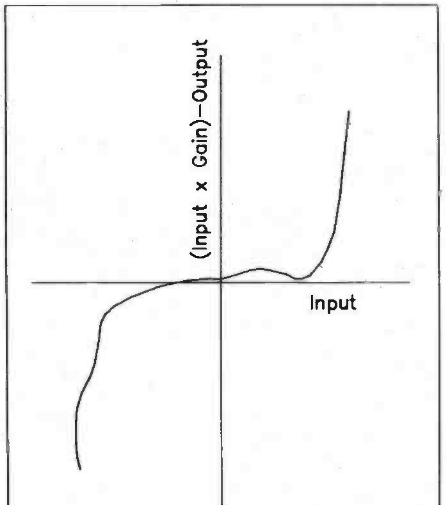


Figure 1d. Transfer error characteristic: the difference between what you want and what you get is plotted against what you put in.

It is possible to correct phase-shift of a sinusoidal waveform easily, because a sine-wave consists of only one frequency. This is just a basic fact, it doesn't make sense (except to philosphers) to ask why. So we could apply a sine-wave signal, attenuate and phase-correct the output signal and subtract from the input signal. What we would be left with would be the distortion. What would it look like? It turns out, and can be proved mathematically, that it consists of signals at frequencies which are exact multiples of the input frequency. These are called 'harmonics', the second harmonic at twice the input frequency, the third at three times and so on. We can express these mathematically as mf_1, where f_1 is the input frequency and m is any whole number greater than 1. The number m is called the 'order' of the distortion. The component of the output signal at the input frequency ($m = 1$) is called the 'fundamental'. It turns out, also, that the ratio of the r.m.s. value of the distortion signal to that of the whole output signal is a very useful measure of how bad the distortion sounds. What the above technique measures is called 'total harmonic distortion' (THD), and is traditionally expressed as a percentage, although there is a welcome trend to express it in decibels. It is this type of distortion which, usually in very small amounts, is quoted in amplifier specifications. It is quite possible to make a simple test rig along the above lines, as we shall see later.

Harmonics in music

Harmonics are what give the different musical instruments their individual tone-colours or 'timbres'. Only a novelty instrument called the ocarina and (on some notes) the flute, produce sine-waves. These harmonics, therefore, are part of the programme signal, and we want to keep them all; what we don't want are extra doses introduced by the equipment.

Spectra

No, we are not about to discuss ghosts! 'Spectra' is the plural of 'spectrum', and a spectrum is a graph of signal amplitude against frequency. A noise signal gives a more or less continuous graph, but a sine-wave consists of only one frequency, so the graph is just a single vertical line (a spectral line), as in Figure 2a; Figure 2b shows the output of an amplifier fed with a sine-wave signal and producing harmonics. Just by looking at this, we can tell that the amplifier is not push-pull, because there is at least as much even-harmonic distortion as odd-harmonic, whereas the former would be more nearly cancelled out, even in a poor push-pull design. Also, we can be fairly sure that the amplifier has a large amount of negative feedback, because, although each harmonic is not very big, there are high-order harmonics marching away into radio frequencies without getting much smaller.

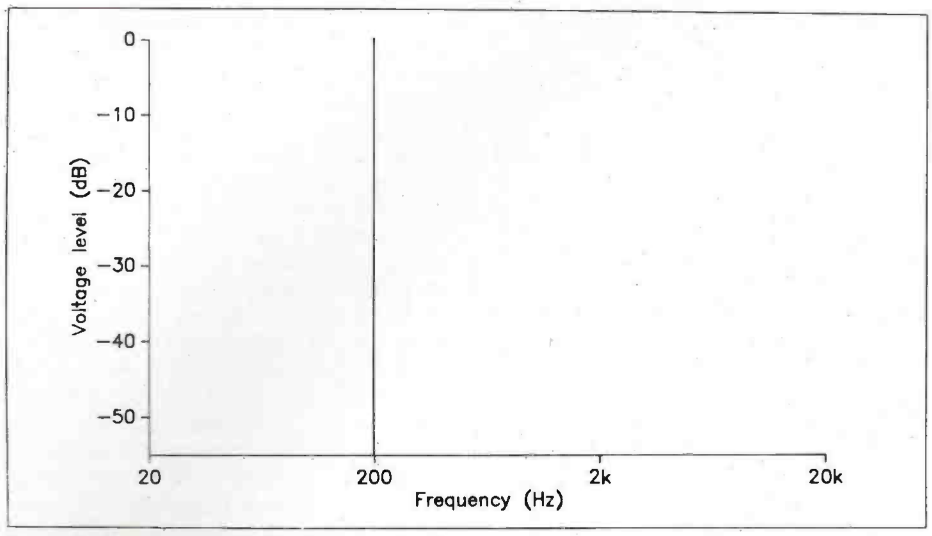


Figure 2a. Spectrum of a 200Hz sine wave signal.

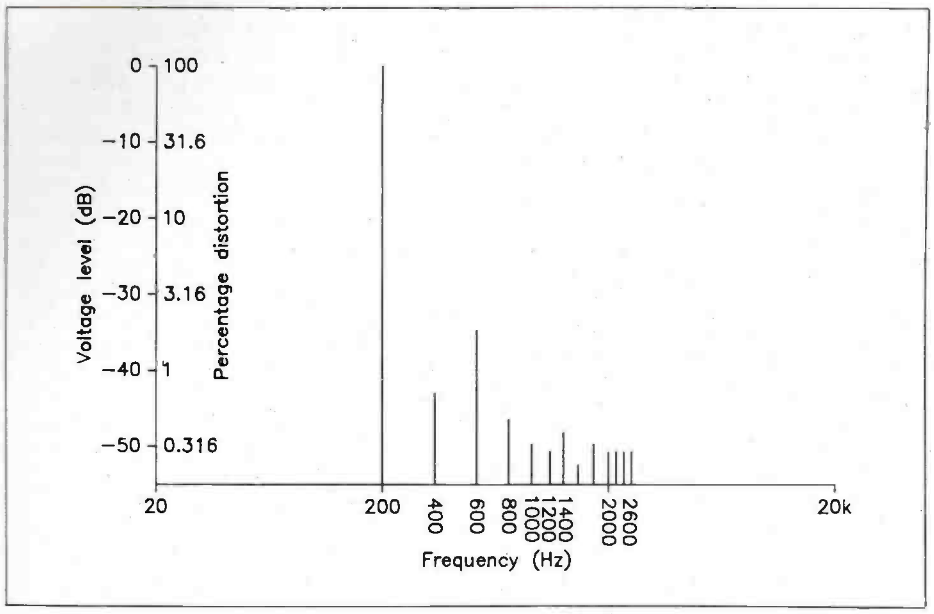


Figure 2b. Spectrum of amplifier output with 200Hz sine wave input showing harmonics up to the 13th.

Intermodulation

If we apply simultaneously two sine-wave signals of different frequencies to an amplifier with either of the types of non-linearity shown in Figures 1b and 1c, it can be shown mathematically that the output signal contains not only harmonics of both input signal frequencies but also signals at new frequencies. These can be expressed by the general formula $mf_1 \pm nf_2$, where f_1 and f_2 are the input frequencies, and m and n are any whole numbers. For example, if $m = 1$ and $n = 1$, we get $f_1 + f_2$, the 'sum frequency' and $f_1 - f_2$, the 'difference frequency'. The 'order' of the distortion is given by the sum $(m + n)$, so the sum and difference frequencies are second-order components of 'intermodulation distortion'. Unless the bends in the transfer characteristic are very sharp, we don't get significant amounts of distortion signal due to very high values of m and n (although they do occur in r.f. amplifiers and, especially, frequency multipliers).

In audio practice, we usually only need to measure second and third order components. With two input signals, there are four third order components: $2f_1 + f_2$, $2f_2 + f_1$, $2f_1 - f_2$ and $2f_2 - f_1$. For example, if f_1 = 262Hz and f_2 = 300Hz, the third order components are 854Hz, 922Hz, 194Hz and 398Hz. Now, the input frequencies just happen to be musical notes C and E, which blend well together (making a chord called a major third) but the new frequencies are a bit below A flat, a bit above A sharp, a bit below G and a bit above G, in different octaves. This represents a combination of a major triad and two sixth chords, played on an out-of-tune piano, and will sound very nasty. (Of course, composers do write such chords, but we are talking about *every* major third being converted into something the composer did *not* write). The second order components are 592Hz and 68Hz,

Limited bandwidth

Measuring harmonics is all right as far as it goes, but it only goes up to 6.7kHz. Above this frequency, the third and higher harmonics (which are usually the most significant in modern audio amplifiers; the even harmonics are much reduced by push-pull techniques) fall above the conventional 20kHz upper limit of the audio frequency range. If the harmonics are inaudible, the sound will be perfect, won't it? No, it won't, and to see why we need to put in more than one sine-wave simultaneously. Programme material has a complex waveform which is equivalent to many sine-waves of continually varying amplitude and frequency, but it cannot generally be used for measurements because there is far too much variation between one type of programme and another. It is possible to do subjective tests of amplifier distortion with programme signals, however, as we shall see. The next step after one sine-wave is two sine-waves, so that is what we shall consider next.

Signal Generator.

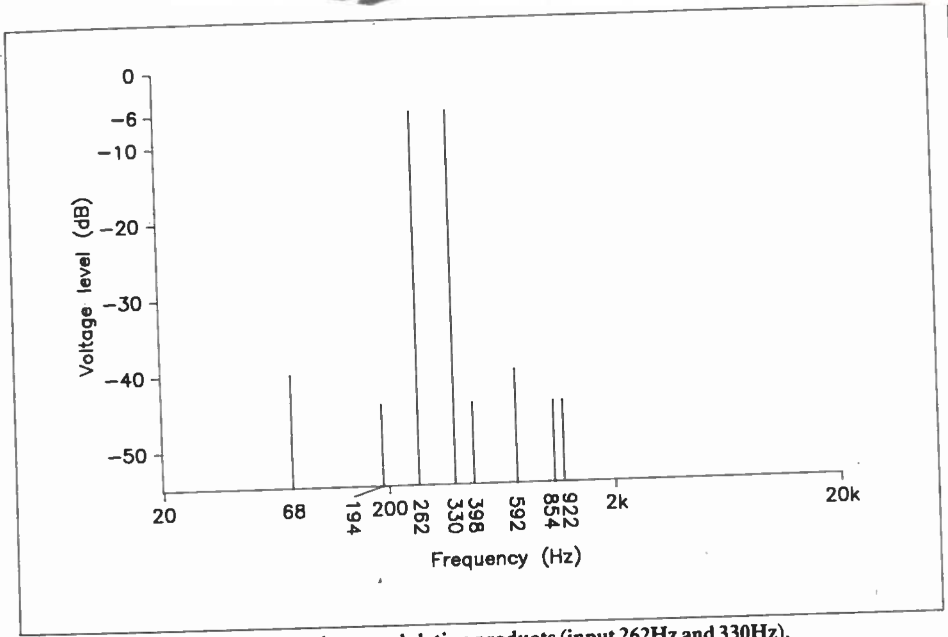


Figure 2c. Spectrum of two-tone intermodulation products (input 262Hz and 330Hz).

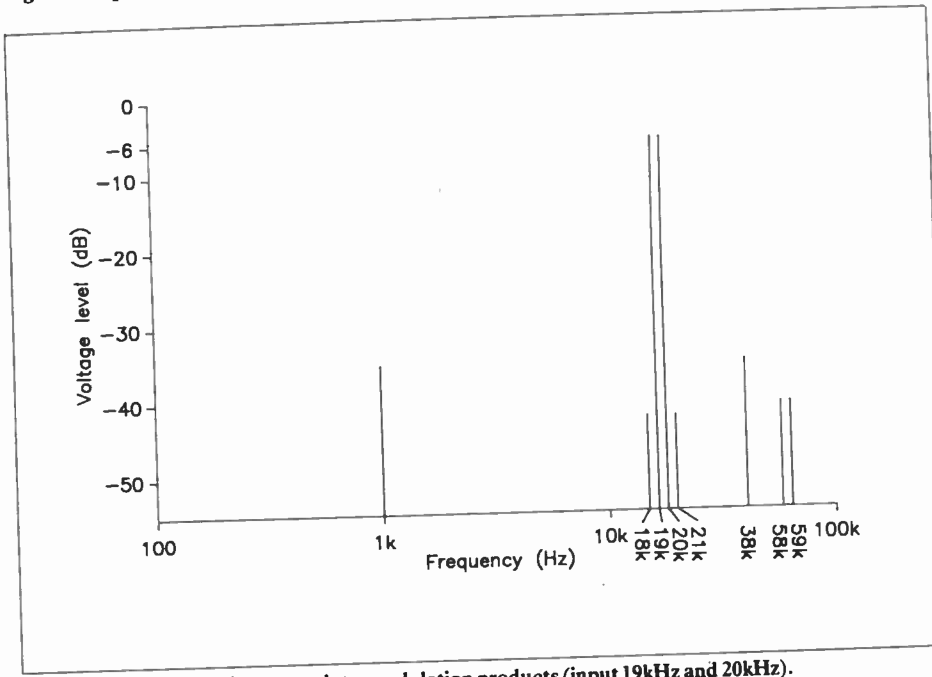


Figure 2d. Spectrum of two-tone intermodulation products (input 19kHz and 20kHz).

which are a bit above D and a bit below C sharp. We now have two out-of-tune second chords to add to the cacophony, and we can draw two useful conclusions. Firstly, intermodulation is bad news for musical reproduction, and secondly, while we had two input frequencies which were quite close together, just within a third of an octave in fact, the output frequencies range from 68Hz to 922Hz, over three and a half octaves! This spreading of the signal spectrum (shown in Figure 2c) is in itself a bad thing, because it may present parts of the system with frequencies that they were not meant to handle and don't handle well. Suppose, for instance that the amplifier in the above example was the mid-range amplifier in a 'tri-amped' speaker system. The mid-range speaker is going to get a portion of 68Hz signal now and then, and it will undoubtedly distort on this signal, introducing harmonics and further intermodulation products, even though the 68Hz signal amplitude is small.

Distortion at high frequencies

We saw that harmonic distortion measurements are not much use above 6.7kHz, because the harmonics fall outside the audio band. The situation is worse for amplifiers intended to cover only part of the audio range, as in active loudspeaker systems. Intermodulation measurements provide a way out of the problem, and for this reason should be more widely known. It can be shown mathematically that, provided higher order components (which can sometimes produce cancellation effects) are negligible, the amplitudes of the two second-order products are equal (at the point where they are generated; subsequent stages in the amplifier may not have the same gain at both frequencies) and the amplitudes of the four third-order products are also equal (with the same proviso). Furthermore, there is an exact relationship between the amplitudes of the intermodulation products and those of the harmonic products of the same order (but again, later amplifier stages may alter this somewhat). For equal amplitudes of the two signals at f_1 and f_2, the second-order intermodulation products are twice as big as the second harmonic distortion product, and the third-order intermodulation products are three times as big as the third harmonic distortion product (and this applies generally: the nth-order intermodulation products are each n times as big as the nth harmonic). It rarely turns out like this in practice, however, because we usually measure at the output of the amplifier, whereas the distortion is generated somewhere within the circuit, and the following stage affect the results. Nevertheless, we can compare the two sorts of distortion product roughly. The intermodulation products have the advantages that, being bigger, they can lead to a more sensitive measuring technique, and that some of them fall well within the pass-band of the amplifier. For example, to look at the distortion of an audio amplifier at really high frequencies, we could put in signals at 18kHz and 20kHz. These would give a second order product at 2kHz and a third order product at 16kHz, both within the audio range. Since these are both difference-frequency components ($f_2 - f_1$ and $2f_1 - f_2$), such a measurement is called a measurement of 'difference-frequency distortion' (Figure 2d). It was invented by the CCIR (Comite Consultatif International de Radio, International Radio Consultative Committee), and thus used to be called 'CCIR intermodulation distortion', which is less than helpfull in explaining what it actually is.

Measurement at low frequencies

The measurement of distortion at low frequency used to be much more important than it is now. This was because transformers, if badly-designed or incorrectly-operated, could introduce considerable amounts of distortion, especially third-order, at low frequencies. It is now however, unusual to find transformers in the signal path of modern household or even semi-professional audio equipment. But they are extensively used in broadcasting equipment, and can meet the most stringent quality requirements when properly (but expensively!) designed.

All right, you may well say, there is no problem with the harmonics of low frequencies falling outside the audio band, so why not just measure harmonic distortion? There is some force in this argument, and for many amplifiers there is a good correlation between harmonic and intermodulation distortion at low frequencies. However, the subjective effects of intermodulation between low and high frequencies are more obvious than those of similar amounts of harmonic distortion alone, so it is not unreasonable to measure the intermodulation directly. To do this, a low-frequency sine-wave signal is applied to sweep the amplifier up and down its transfer characteristic. A smaller, high

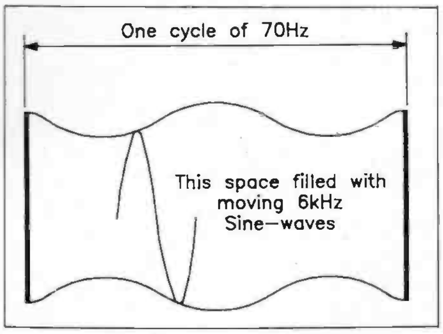
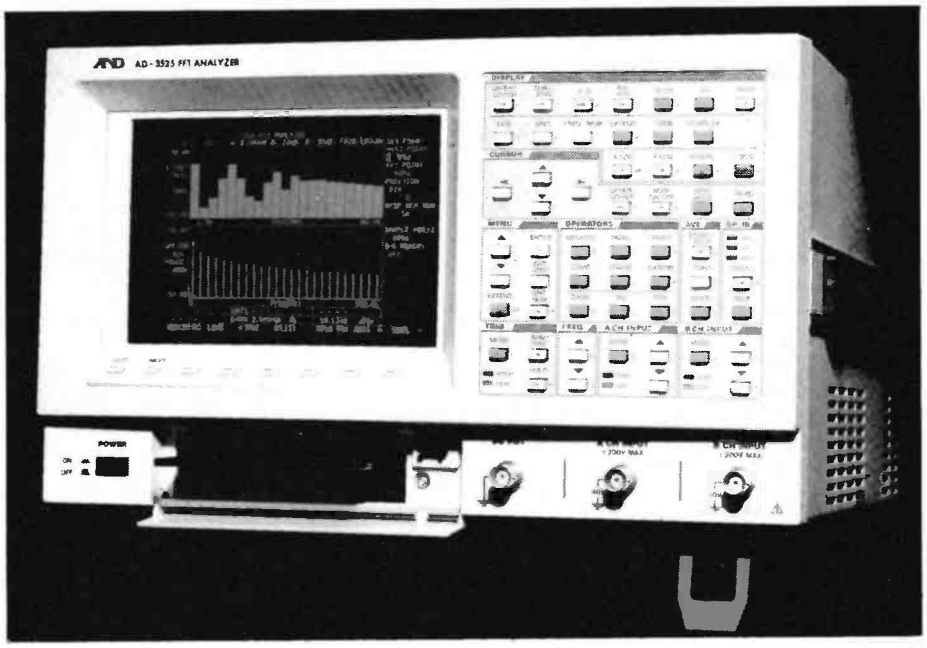


Figure 2e. Waveform of output from two-tone (inter)modulation test signal (70Hz and 6kHz) with 70Hz and harmonics filtered off. Result is an amplitude-modulated 6kHz sine wave, x-deflection for the display is the 70Hz input signal.

frequency sine-wave is added, and the second-order curvature of the transfer characteristic (which is equivalent to variation of gain) causes this signal to be amplitude-modulated by the low-frequency signal (and its harmonics). We can see this by examining the expression for the second-order intermodulation pro-



FFT Analyser.

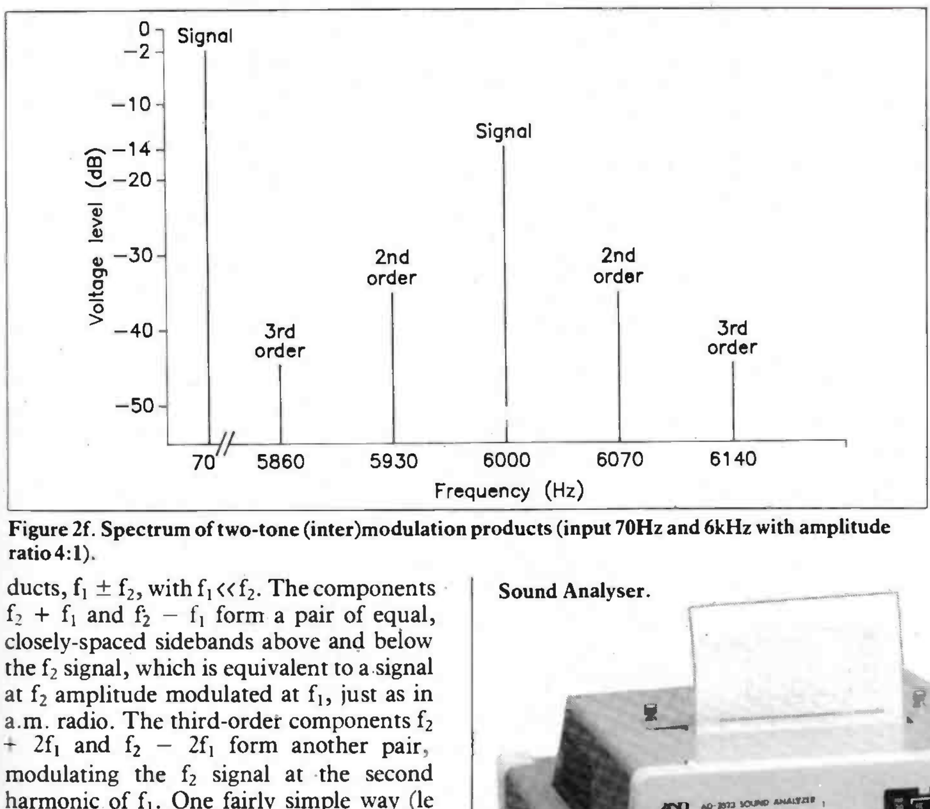


Figure 2f. Spectrum of two-tone (inter)modulation products (input 70Hz and 6kHz with amplitude ratio 4:1).

ducts, $f_1 \pm f_2$, with $f_1 \ll f_2$. The components $f_2 + f_1$ and $f_2 - f_1$ form a pair of equal, closely-spaced sidebands above and below the f_2 signal, which is equivalent to a signal at f_2 amplitude modulated at f_1, just as in a.m. radio. The third-order components $f_2 + 2f_1$ and $f_2 - 2f_1$ form another pair, modulating the f_2 signal at the second harmonic of f_1. One fairly simple way (le Bel's method) of measuring the result of this test is to filter off the low frequency signal f_1 and display the modulated high frequency signal on an oscilloscope. The amplitude of the modulation relative to the carrier can be measured on the screen (Figure 2e). Originally, further calculations from this result were suggested, but these are not now considered very reliable.

The standard way of doing this test is to put into the amplifier a large-amplitude, low-frequency sine-wave, at 70Hz for example, and a high-frequency signal (e.g. at 6kHz) of one-quarter the amplitude of the low-frequency signal. This acts as a 'probe', to measure the gain at each point on the transfer characteristic, averaged over one quarter of the characteristic. At least, this is the conventional explanation, but, if it were true, the method would tend to show up sharp non-linearities, such as crossover distortion; better if the amplitude of the probe signal were reduced (thus reducing the smoothing effect of the averaging). In practice, the ratio of 4:1 in amplitude seems to produce the most sensitive measurement. This method was invented by the SMPTE (Society of Motion Picture and Television Engineers), and used to be called a measurement of 'SMPTE intermodulation distortion', but it is now called 'modulation distortion', a term originated by P.G.A.H. Voight and re-invented independently for the IEC (International Electrotechnical Commission) by the author much later. We have already seen that modulation is one of the effects produced. The spectrum of a typical output signal produced in this test is shown in Figure 2f.

Sound Analyser.

Next Time

In part two we will continue out discussion with Total Difference – Frequency Distortion (TDFD) and some measurement techniques.

Photographs of AND analysers courtesy of
Hakuto International (UK),
Eleanor House,
33-35 Eleanor Cross Road,
Waltham Cross, Herts. EN8 7LF.
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THE LAMENT OF THE ENGINEER'S WIFE

PART 1 – WHY DO ENGINEERS ALWAYS WANT TO IMPROVE THINGS?

by Marion Hearfield

A few years ago, after twenty years of working for other people, my husband started his own electronics design consultancy. He now works for himself (and us) from home. This is great. It means that we can go to the pub for lunch whilst the kids are in school (not that we often have the time). On the other hand, there is no getting away from work, and weekends just do not exist if we have a deadline to meet.

My dilemma is acute if I am helping to meet the deadline, but I have now got it down to a fine art. Not the kind of Fine Art I learned about at school, but the kind you need to run a home and a business at the same time (see Figure 1). Somehow clothes do get hurled into the washing machine in between printing the pages of long documents. I can whizz round with the vacuum cleaner or make the bed while the soldering iron is warming up, or keep an eye on the printed circuit boards etching in the kitchen whilst I tidy up downstairs. If I don't do the shopping first, the days flash by in a flurry of receipts and cash books and VAT returns and tax returns and telephone calls and invoices and research for articles and going to exhibitions – and we have pizzas *again* for dinner.

As in all good organisations, we have a fair division of labour – he does the clever bits and I do the boring bits. This suits us both very well. I enjoy the boring bits (he doesn't) and anyway they tend to drive him nuts. But if I try to help with the clever bits why is it me that drives him nuts? Where does he get that awful patient expression from? It reminds me of how I used to feel when our children were little and ... ah, yes, well.

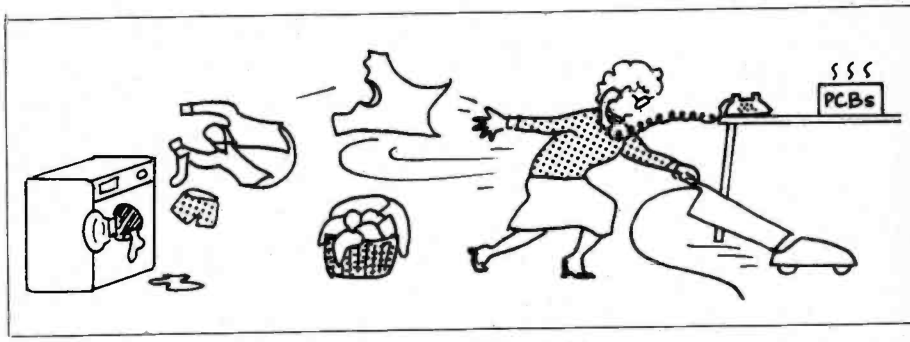
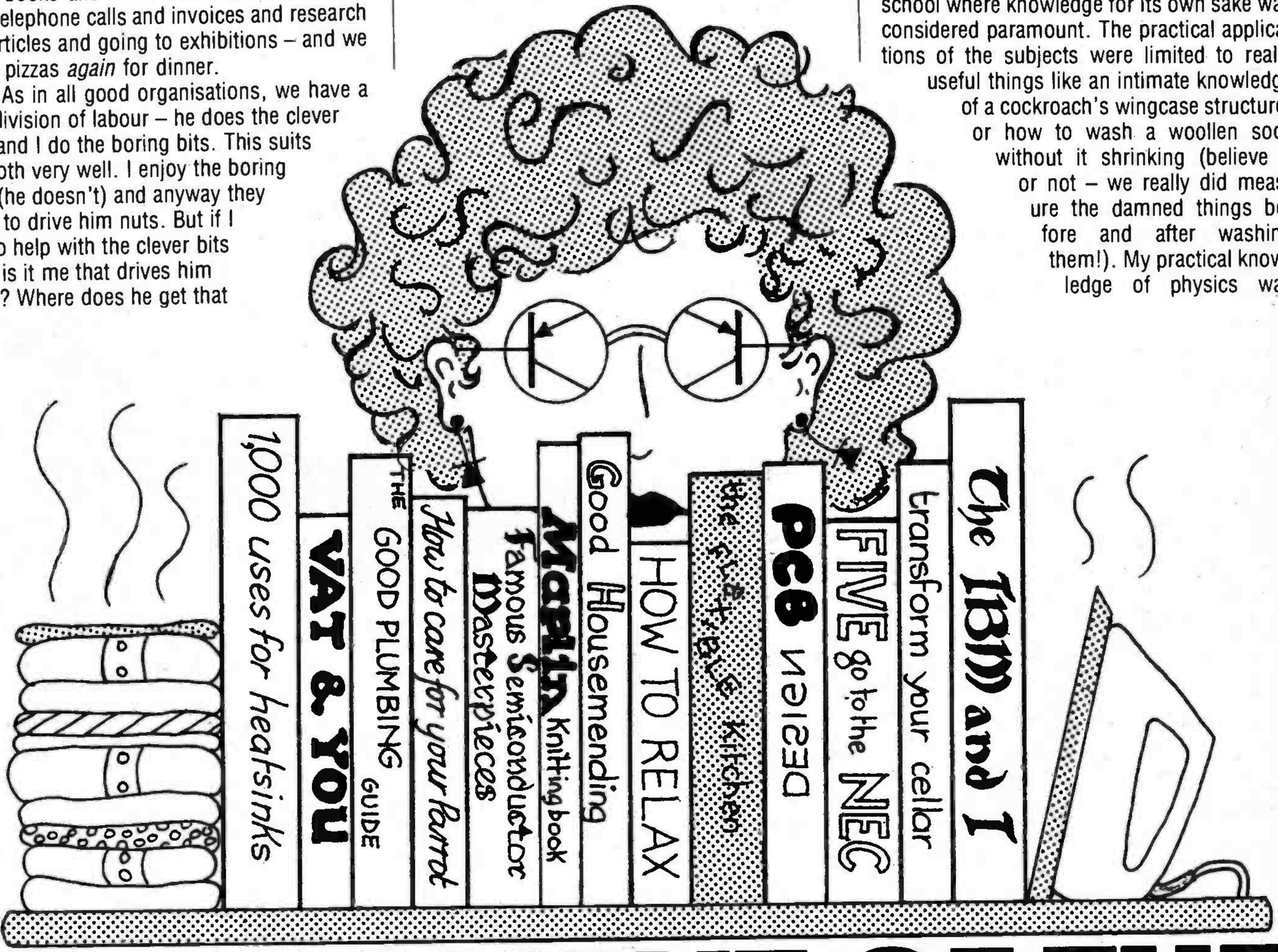


Figure 1. The engineer's wife – half housewife and half lab technician.

In between all this breadwinning activity (or at least sweeping up the crumbs) I get on with the ironing, or the plastering, or the decorating. It was whilst I was ironing that this lament surfaced in my mind. Being a dutiful engineer's wife I finished ironing before I reached for my word processor.

Thinking back over those twenty-odd years I realised that the unfairness of being the non-engineering wife of an engineer started early. Why did everyone start using transistors just as I finally understood valves? It continues to this day:– why was it fine soldering and not fine print that showed me that I needed reading glasses?

I never did any 'proper' science beyond the third year at grammar school – I was on the Arts side. In the late 1950s it was the sort of school where knowledge for its own sake was considered paramount. The practical applications of the subjects were limited to really useful things like an intimate knowledge of a cockroach's wingcase structure, or how to wash a woollen sock without it shrinking (believe it or not – we really did measure the damned things before and after washing them!). My practical knowledge of physics was



zero and, what is worse, I didn't realise that it mattered. I thought that I had had a good education at a progressive school.

Then I met this bright young engineering student, mad about amateur radio and planes and fixing things. I wanted to discuss CND and George Orwell; he wanted to show me how a triode pentode valve worked. We still have it in a box, somewhere, in case it comes in useful. I should have realised what engineers are really like when my parents bought me a record-player and the budding engineer offered to build a better amplifier for it. He did, and it was better, and this was the start of a life-time of *improving things*.

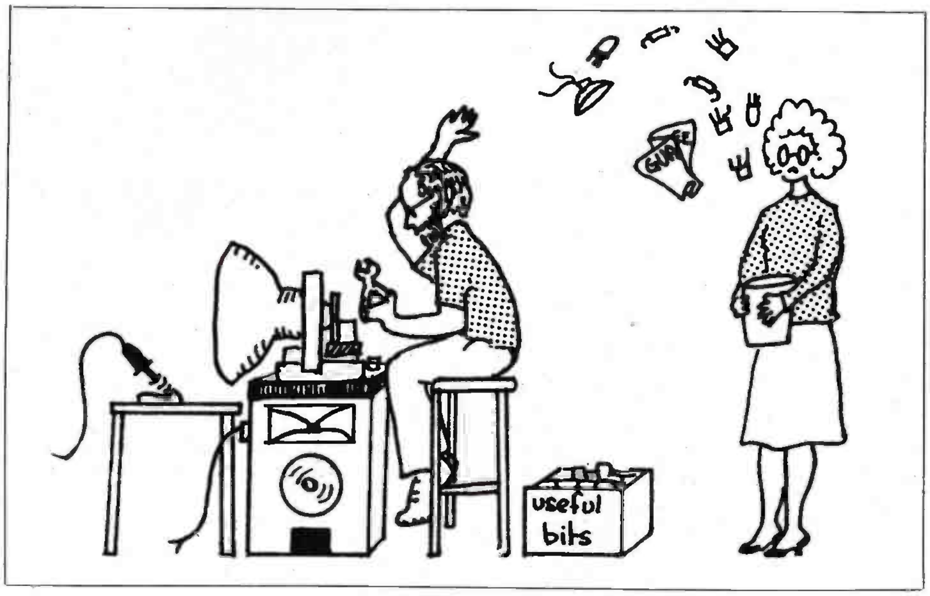


Figure 2. An engineer's wife is always useful for cleaning up the mess.

Why do engineers always want to improve things? Our very first brand-spanking-new television set was modified as soon as we got it home (see Figure 2). The budding engineer was by now a graduate engineer, with an accumulated store of useful tools and components, and a technical gleam in his eye as he surveyed our first major electronic purchase. "What about the guarantee?" I wailed, but the engineer knew he could build a better sound system, and feed it through an external speaker. We missed a few evenings' television because we were working on the new circuit boards, but of course the sound was better when he had finished. The improved television stood firmly on a splendid cinema speaker donated by my father-in-law and modified by the engineer (the sound quality was amazing, by the way). Nothing went wrong so we didn't need the guarantee anyway.

That cinema speaker was the first of many things passed on because we might be able to find a use for it. My mother-in-law is also the wife of an engineer, so I suppose it's my own fault that I didn't really take much notice of this practical example of what an engineer's wife has to put up with. Why hadn't she married a bus driver or a consultant neurologist? Bus drivers and consultant neurologists don't take their work home, and they don't keep boxes of useful bits in their cellars to pass on to their children when they move house or have a clear-out. A lot of the components that went into that television came from my father-in-law. I am pleased to say that the traffic is now two-way, and we vie with each other to leave the larger box at the other one's house.

At least you could see what you were building circuits with in those days. That television sound system was built on a big Vero board, using chunky transistors, big heat sinks, and resistors which didn't disappear for ever as soon as you dropped one on the carpet. Who uses big heat sinks nowadays? If anybody needs one we have a box full in the cellar, just in case they come in useful.

I am constantly baffled by the speed with which components change their size, shape and capability. In my earliest non-engineering days you could watch a valve warm up and practically see the signal passing through the circuit. Nowadays I have to remember to earth myself each time I approach the bench. I might accidentally touch a fragile little black spider-thing no bigger than a finger-nail that cost £8.95 and it's the last one we have in stock until the replacements come. Given a resistor colour chart (thank-you, Maplin) I can sort components, but I must admit that I am very glad that we don't have room for a surface-mount machine. We have got enough to do without starting down that route.

Why do engineers' families always have to wait, because building 'the system' ourselves would be so much cheaper and result in such better quality? We all get so used to not buying 'it' ready-made, because we can build 'it' ourselves, that we don't realise we are actually doing without something which would be really useful, or pleasurable, if only we had one.

This philosophy applies even in areas where we start off with no real skills, though we have acquired them by the time we have finished. So we have designed and installed our own central heating systems, plumbed in our own dishwashers, mended our own cars and built our own cupboards (out of real wood; none of your laminated chipboard in our house. Well, not much).

Or we used to – one of the ironies of the last few years is that we have been so busy that we have done just the designs then passed them on to real plumbers, joiners and builders. Not, you notice, electricians. We (the engineer) said that of course we would do the wiring ourselves. But the engineer was so busy creating an elegant filter-design program on his new computer that he hadn't got time right then to install a new mains socket for the dishwasher in our nearly-completed new kitchen. Why not? Because he doesn't do the washing up, that's why not. I would also have liked to filter the plate-scrapings though the waste disposer. It was probably high-pass and low-pass, and elliptical for all I knew, but it wasn't wired in.

Granted, the kitchen actually required a complete re-wire. During a 'weekend off' we got as far as channelling in the conduit and socket boxes, and feeding in the cables. So why did we stop, just because we had to take up the floorboards across three bedrooms and my office to get the ring return in?

After waiting for eleven years for her engineer husband to complete their half-finished home-built hi-fi system, a musical friend of mine finally went out and bought a tape player and cassette versions of her favourite but unplayable records. I hope I don't have to wait so long to get the kitchen finished.

At least I now have no hesitation in hacking a channel in the plaster to bury a length of conduit. I have an intimate knowledge of the mysterious spaces underneath our floorboards (see Figure 3). Being an engineer's wife, I have drawn maps of the cabling and labelled the cables to match: documentation is an important part of our professional lives, so I don't see why it shouldn't apply to the domestic side as well. Our children have been involved too (though sometimes on the basis of 'It's your room so you can just put your book down and come and help'.) They can both now be relied on to notch joists, they can lay cable without putting twists in it, and they are both competent plasterers when it comes to covering up the conduit. But I feel they think that they suffer, being engineer's kids, and having to help to get the house intercom and TV distribution coax threaded through the walls and floors of our house instead of paying someone else to do it.

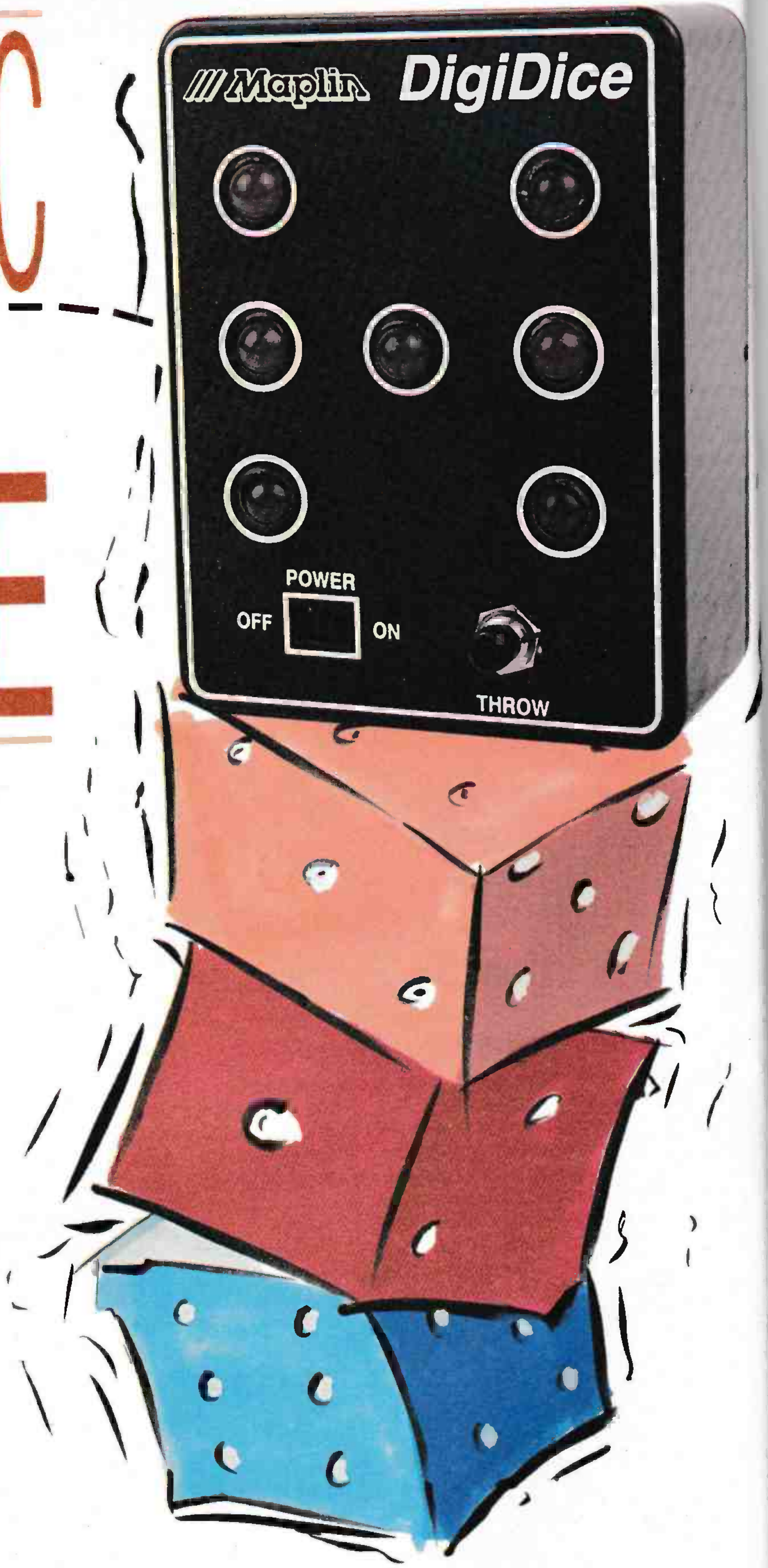
Why do engineers' kids get kits for

Figure 3. Under the boardwalk!

Continued on page 39.

ELECTRONIC

DIGIDICE



by Gavin Cheeseman

Introduction

Most games incorporate a degree of chance in the rules; this random element can take a variety of forms but in many cases it is obtained using dice. A standard die consists of a small cube of wood or similar material. Each of the six sides of the cube are marked with a number of dots corresponding to the numbers 1 to 6. In order to produce a result, the die is shaken in a small container and thrown onto a flat surface; the side of the die which lands facing upward indicates the result.

With an ordinary die, as long as it is manufactured properly there are unlikely to be any problems with obtaining a random result; however with an electronic version of the die, producing a truly random result can be a problem. The DigiDice uses a high frequency temperature controlled oscillator, a binary counter and a D-type latch to produce a pseudo-random result that should be for all practical purposes comparable with that obtained from a real die. The result is displayed by seven large (8mm) LED's which are arranged in a similar configuration to the numbers on a real die.

Circuit Description

Referring to Figure 1, the DigiDice circuit operates by latching a decoded output from a binary counter which is driven by a high frequency, temperature sensitive oscillator (clock). IC1a forms the basis of the high frequency oscillator, the operating frequency of which is determined by resistor R4, capacitor C3 and thermistor TH1. Since the resistance of TH1 is determined by temperature, the frequency of oscillation is also temperature dependent. Because the ambient temperature is constantly variable in many environments, the addition of the thermistor in the oscillator feedback loop helps to increase the random element of the circuit. The output of the oscillator is fed to the input of binary counter IC2, which produces a constantly cycling parallel binary output from 0 to 5 (corresponding to the numbers 1 to 6 on a die). Signal diodes, D2-D9 decode the output from the binary counter so as to provide a suitable format to feed into the latch (IC3). When push switch S2 is pressed and released, a pulse is applied to the clock input of IC3 and the code present on the data input is held in the latch until another pulse is received. The data output from IC3 is fed to LED driver transistors TR1-TR4 via current limiting resistors R10, R11, R13 and R14. It is necessary to invert the data output on pin 4 of IC3 before feeding it to TR4, in order to provide the correct code for the LED's and IC1d is used for this purpose. To reduce the average current drain, the drive signal to the LED's from the latch is multiplexed;

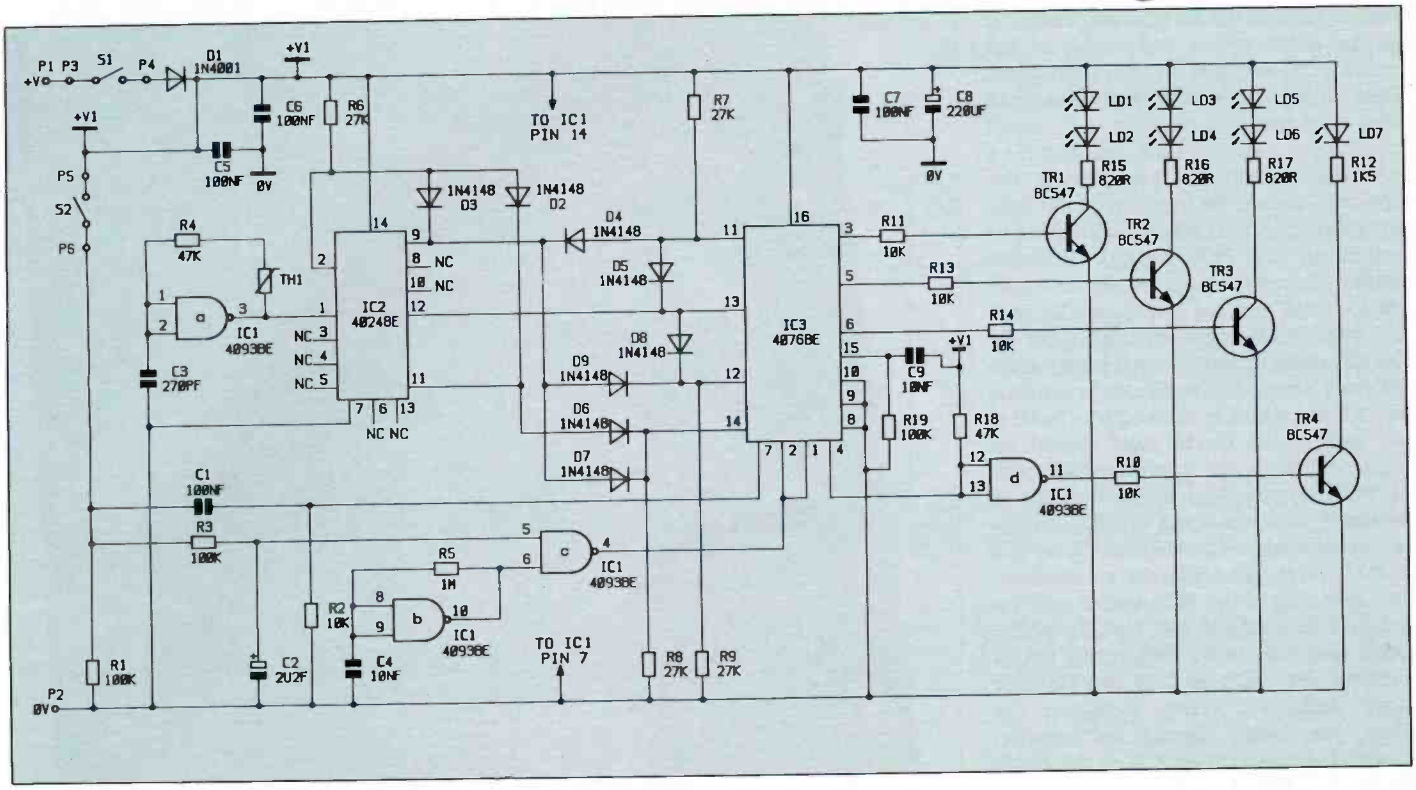


Figure 1. Circuit Diagram.

this is achieved by applying the output from NAND gate IC1c to the output enable line of IC3. The output state of IC1c is determined by the state of S2, C2, R3 and the multiplexing oscillator comprising IC1b, R5 and C4. R2 and C1 determine the time constant for the latch input pulse and C9 together with R19 provides a start-up reset pulse for IC3. The trigger pulse timing is arranged such that the LED's are switched off during the period that the latch trigger pulse occurs; this helps to prevent aesthetic problems with spurious triggering caused by a noisy switching characteristic. Diode D1 is included in the circuit to prevent any risk of damage should the power supply be accidentally reversed. Capacitors C5, C6, C7 and C8 decouple the supply rail at different points in the circuit to both low and high frequency signals. Each IC has individual high frequency decoupling to help prevent false triggering or instability.

Construction

The DigiDice project is easy to construct and requires no special tools or test equipment. The circuit is constructed on a high quality fibre glass PCB which has a printed legend to facilitate component positioning. Before attempting any construction, check the components with the Parts List to make sure that everything is correct and that nothing is missing; if all is well, then construction may commence.

Insert and solder the components onto the PCB referring to Figure 2. It is best to start with the low profile components such as the resistors and wire links as these can be harder to fit once the larger components are on the board. The links can be made from component lead off-cuts or tinned copper wire of a similar diameter. All component leads should be kept as short as possible and the height of the components above the component side of the PCB must be kept to a minimum to avoid problems when housing the

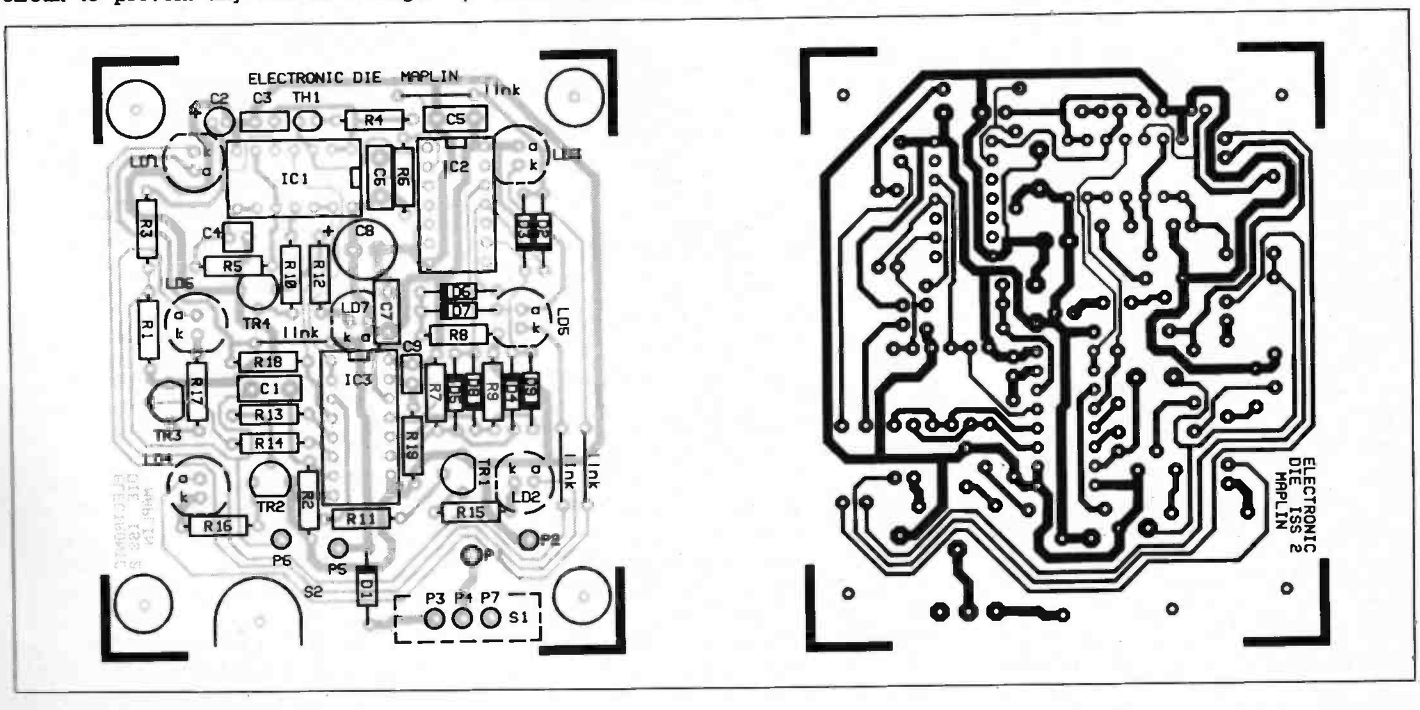


Figure 2. PCB Layout.

project. Next fit the IC sockets, ensuring that the notch at one end of the socket corresponds with that on the PCB legend. When fitting the electrolytic capacitors make sure that you observe the correct polarity; the negative lead, marked by a negative (−) sign on the side of the capacitor, should be inserted in the hole opposite to that marked as the positive (+) symbol on the PCB legend. Exercise caution when soldering the semiconductors as these can be easily overheated. First insert and solder diodes D1-D9. As with all the semiconductors, it is important that the polarity of the diodes is correct; the cathode, which is marked by a band at one end of the diode case should be positioned such that it corresponds with the PCB legend. Next fit the transistors, remembering once again that the transistor case should be aligned with the outline on the legend. The LED's are soldered on the *track* side of the PCB and should be mounted 5mm above the surface of the board (see Figure 3). Take care not to overheat the LED's as they can be very easily damaged. When mounting the LED's, the leads should be inserted through the holes in the PCB as this helps to avoid damage to the tracks; even with this precaution it is still a good idea not to bend the leads of the LED's once they are in place as any excessive force could lift the track. Next, fit the PCB pins. The pins should initially be inserted into the appropriate holes in the PCB and pressed home using a hot soldering iron. Once in place, the pins can then be soldered. Do not fit the IC's into the IC sockets until all other components have been soldered. The IC should be inserted such that the notch at one end of the IC corresponds with that in the socket. Slide switch S1 is held in position by three double ended PCB pins (P3, P4 and P7); the switch should be soldered to the pins so that the fixing plate is approximately 10mm above the track side of the PCB as shown in Figure 4.

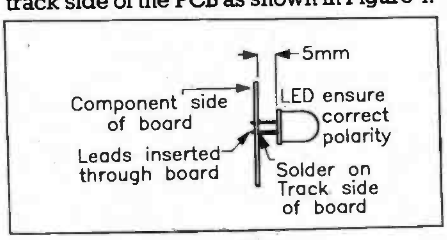
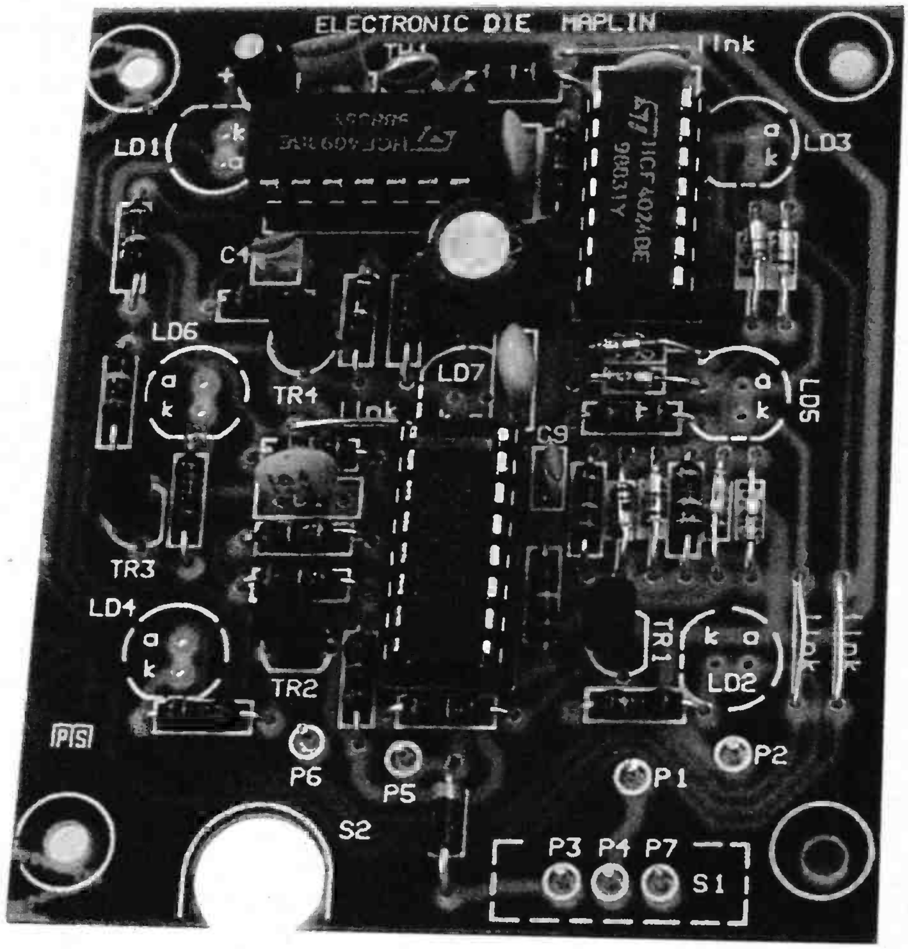


Figure 3. Mounting the LEDs.

P7 is used as a fixing point only and is not connected electrically to any other part of the circuit. It is important that the slide switch is kept straight, such that the lever is vertical, relative to the PCB to avoid problems when housing the unit. Push to break switch S2 is panel mounted and is wired to the PCB with two short lengths of hook-up wire. The wires from S2 are soldered to P5 and P6 (the polarity is not important). Finally, the PP3 battery clip is soldered into position; the red wire is connected to P1 and the black wire is connected to P2. For further information on soldering and constructional techniques refer to the constructers' guide included in the kit.



The PCB.

Testing

Before applying power to the circuit, do double check your work to make sure that all components are fitted correctly and that there are no dry joints or solder short circuits! In particular check the semiconductors and electrolytic capacitors to ensure that the polarity is correct. If a multimeter is available, it is a good idea

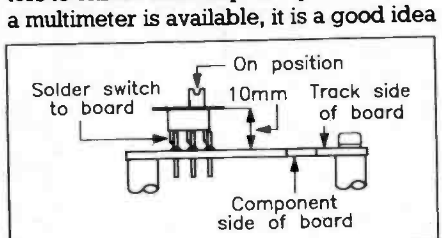


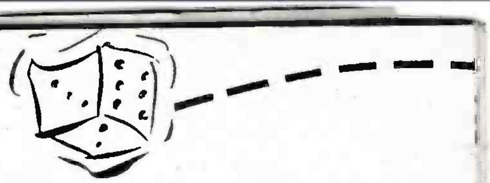
Figure 4. Mounting the Slide Switch.

to check the resistance between the battery clip terminals, with S1 switched to the 'on' position (battery disconnected) to make sure that there are no short circuits; the meter may initially indicate a low resistance but this should rise rapidly as the capacitors in the circuit charge. The DigiDice operates from a 9V, alkaline, PP3 type battery and current drain is dependent on the number being displayed since most of the current is drawn by the LED's. Current consumption is kept comparatively low by the LED multiplexing circuit. Maximum current consumption occurs when the die is displaying number 6 (average current approximately 12mA) as this is when the most LED's are lit.

When you are sure that everything is correct, clip the battery into the battery clip and slide S1 to the 'on' position. After initial switch-on, the display should show number 1 (central LED lit) indicating that the unit is powered up. If push button switch S2 is pressed, the LED should extinguish and when the button is released the display should show a result (a number between 1 and 6) in a similar format to a real die. In order to test the unit, the above process should be repeated until all six numbers have been displayed. Although the results are for all practical purposes random, occasionally a number will be repeated twice or even more times in succession; this effect is normal and occurs in just the same way with an ordinary die.

Housing the DigiDice

It is recommended that the DigiDice PCB is housed in an ABS box type MB2 (Maplin stock code LH21X) and Figure 5 shows the necessary drilling details. The PCB is mounted on the lid of the box using 25mm plastic spacers as shown in Figure 6. Do not over tighten the fixing screws otherwise the spacers could be permanently damaged. An optional adhesive front panel is available for the DigiDice (Maplin stock code JP39N). To fit the front panel, simply remove the protective backing and place the panel in position. Remember to remove any plastic swarf that is left around the drill holes and make



sure that the edges are completely smooth. Ensure that the front panel is aligned correctly with the sides of the box before sticking it down. It is a good idea to press the panel into place using a clean, soft cloth as this avoids marking the surface. Push to break switch S2 is held in position on the front panel using the locking nut provided. Take care not to scratch the front panel when tightening the locking nut. The battery slides into position between the PCB and the lid of the box and does not require any additional fixings. Before placing the lid of the box in position please make sure that the LED's are straight and that they line up with the holes in the front panel. The push switch slides into a slot in the PCB. If everything is correct, the lid can then be fitted and secured in place using the four screws supplied with the box. Fit the rubber feet to the underside of the box; a suitable type of foot for this purpose is Maplin stock code FW38R. Before fitting the feet make sure that the surface of the lid is clean and dry. Carefully remove the protective backing from the feet and press them into position, one at each corner of the lid, avoiding the fixing screws for the lid.

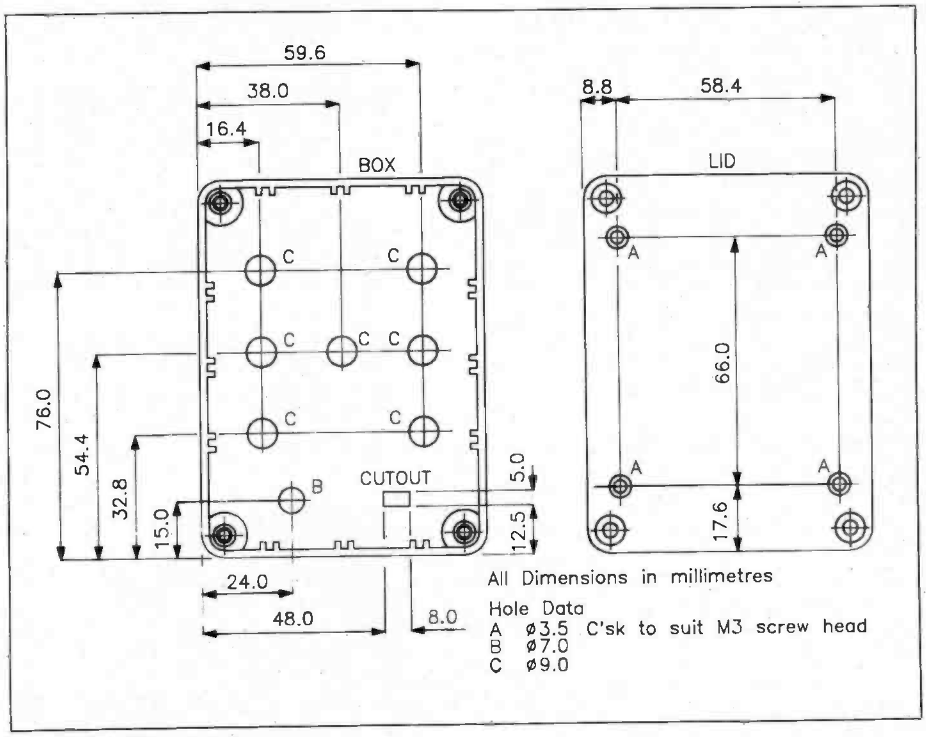


Figure 5. Drilling Details.

Using the DigiDice

The DigiDice can be used in the majority of situations where an ordinary die would normally be employed, for example, in games such as snakes and ladders or ludo; it is of course designed to be used purely for fun and is not intended to be used for serious gambling. Battery life depends on the current consumption of the circuit (which varies) and the type of battery used. A standard PP3 type alkaline battery should provide many hours of operation under normal circumstances. To conserve battery life it is important that slide switch S1 is set to the off position when the DigiDice is not in use. When the brightness of the LED's starts to fade it is recommended that the battery is replaced to preserve correct operation of the unit, since as the battery voltage becomes very low, the randomness of the result could be affected. An alkaline battery is recommended as this usually has a larger capacity than the standard zinc carbon type and therefore allows operation for a longer period.

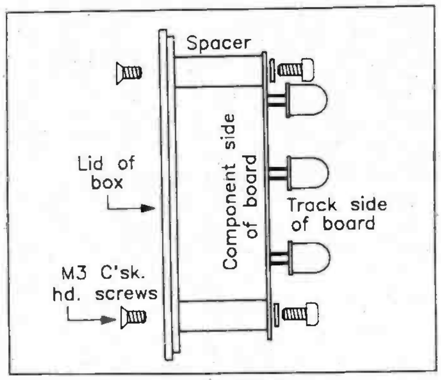


Figure 6. Installing the PCB.

ELECTRONIC DIGIDICE

RESISTORS: All 0.6W 1% Metal Film

R1,3,19	100k	3	(M100K)
R2,10,11,13,14	10k	5	(M10K)
R4,18	47k	2	(M47K)
R5	1M	1	(M1M)
R6-9	27k	4	(M27K)
R12	1k5	1	(M1K5)
R15-17	820Ω	3	(M820R)
TH1	4k7 Thermistor	1	(FX21X)
CAPACITORS			
C1,5-7	100nF Minidisc	4	(YR75S)
C2	2μ2F 63V Minelect	1	(YY32K)
C3	270pF Ceramic	1	(WX61R)
C4	10nF Disc Ceramic	1	(BX00A)
C8	220μF 10V Minelect	1	(JL06G)
C9	10nF Ceramic	1	(WX77J)
SEMICONDUCTORS			
D1	1N4001	1	(QL73Q)
D2-9	1N4148	8	(QL80B)
TR1-4	BC547	4	(QQ14Q)
IC1	4093BE	1	(QW53H)
IC2	4024BE	1	(QX13P)
IC3	4076BE	1	(QW46A)
LD1-7	LED Red 8mm	7	(UK21X)

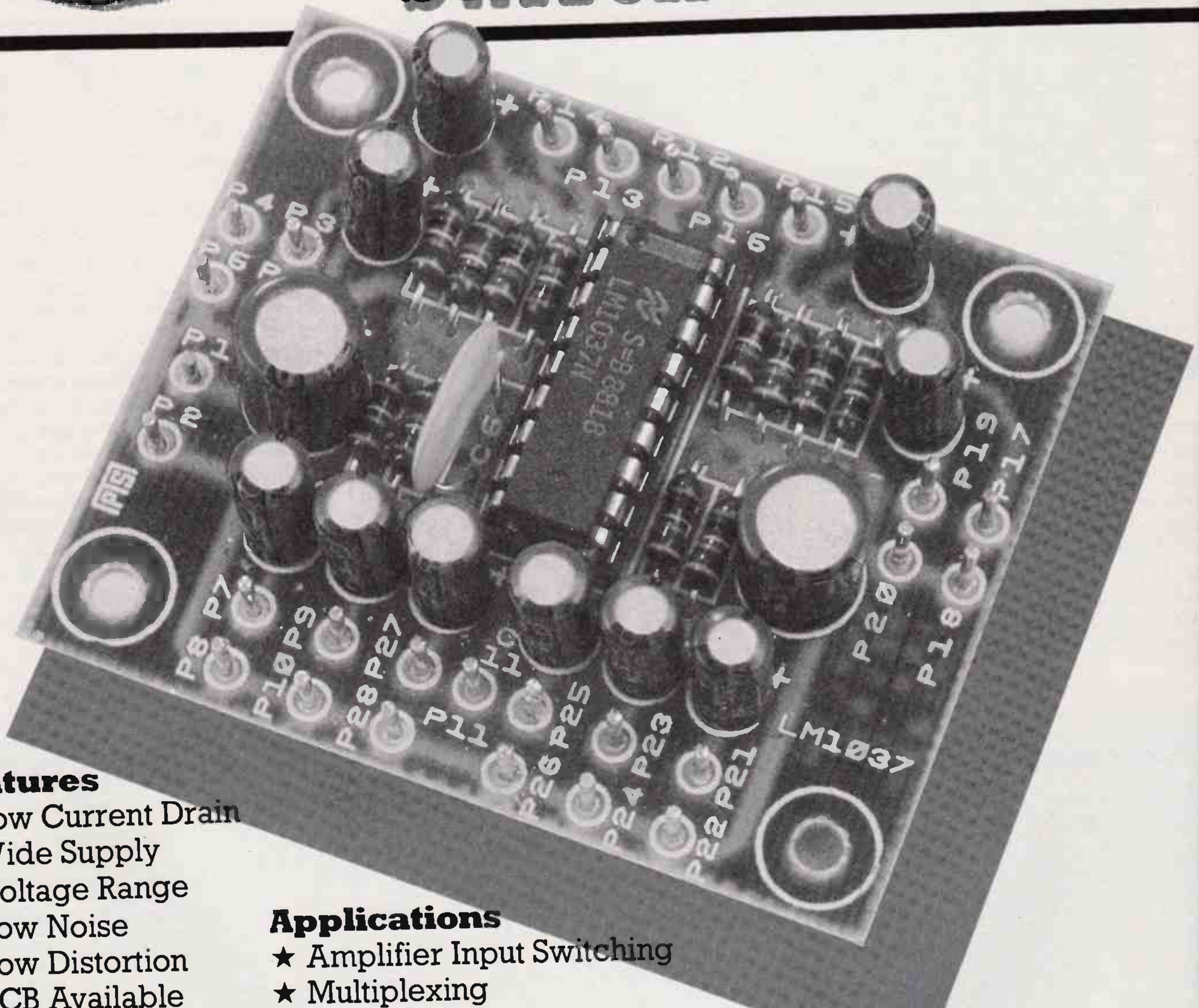
MISCELLANEOUS			
	Constructors Guide	1	(XH79L)
	PC Board	1	(GE12N)
P1-7	Pins 2144	1 Pkt	(FL23A)
	Wire 7/0.2mm Blk.	1 Pkt	(BL00A)
	DIL Socket 14 Pin	2	(BL18U)
	DIL Socket 16 Pin	1	(BL19V)
	PP3 Battery Clip	1	(HF28F)
S1	Slide Switch Single Pole	1	(FF77J)
S2	Switch Push to Break	1	(FH60Q)
OPTIONAL			
	ABS Box MB2	1	(LH21X)
	Insulated Spacer M3 × 25mm	1 Pkt	(FS39N)
	Stick-on Front Panel	1	(JP39N)
	Stick-on-feet Large	1 Pkt	(FW38R)

The above items, excluding Optional, are available as a kit:
Order As LM99H (DigiDice Kit) Price £9.95

The following items are also available separately, but are not shown in our 1989 catalogue:
Electronic Die PCB **Order As GE12N Price £2.45**
Front Panel **Order As JP39N Price £1.56**

DATA FILE

LM1037 DUAL FOUR CHANNEL ANALOGUE SWITCH



Features

- ★ Low Current Drain
- ★ Wide Supply Voltage Range
- ★ Low Noise
- ★ Low Distortion
- ★ PCB Available

Applications

- ★ Amplifier Input Switching
- ★ Multiplexing

General Description

The LM1037 is a dual, four channel, analogue switch incorporating an internal muting facility. The device is suitable for a wide range of switching applications including multiplexing and stereo source selection. Each channel is selected by one of four control inputs. Figure 1 shows the IC pin-out diagram and Table 1 and Figure 2 show typical electrical characteristics for the LM1037.

Parameter	Operating Conditions	Min	Typ	Max
Supply Voltage		5V		28V
Supply Current	Supply Voltage = 12V		6.4mA	8.5mA
Maximum Input Voltage	Supply Voltage = 12V	2.8V	2.9V	3.0V
Operating Temperature		−20°C		70°C
Total Harmonic Distortion (THD)	Signal Input = 1V rms at 1kHz		0.04%	0.1%
Voltage Gain		−0.5dB	0dB	0.5dB
Channel Separation	Signal Input = 1V rms at 1kHz		−95dB	
Control Voltage	High Level	2V		50V
	Low Level			0.8V

Note: Above specifications assume a 12V power supply and an ambient temperature of 25°C.

Table 1. Typical Electrical Characteristics of LM1037

Channel Selection

Channel selection is achieved by applying a DC voltage of between 2V and 50V (maximum) to one of four separate control pins. Each control pin selects a different input channel. It is possible to switch an increased number of channels, using two IC's by connecting the mute inhibit

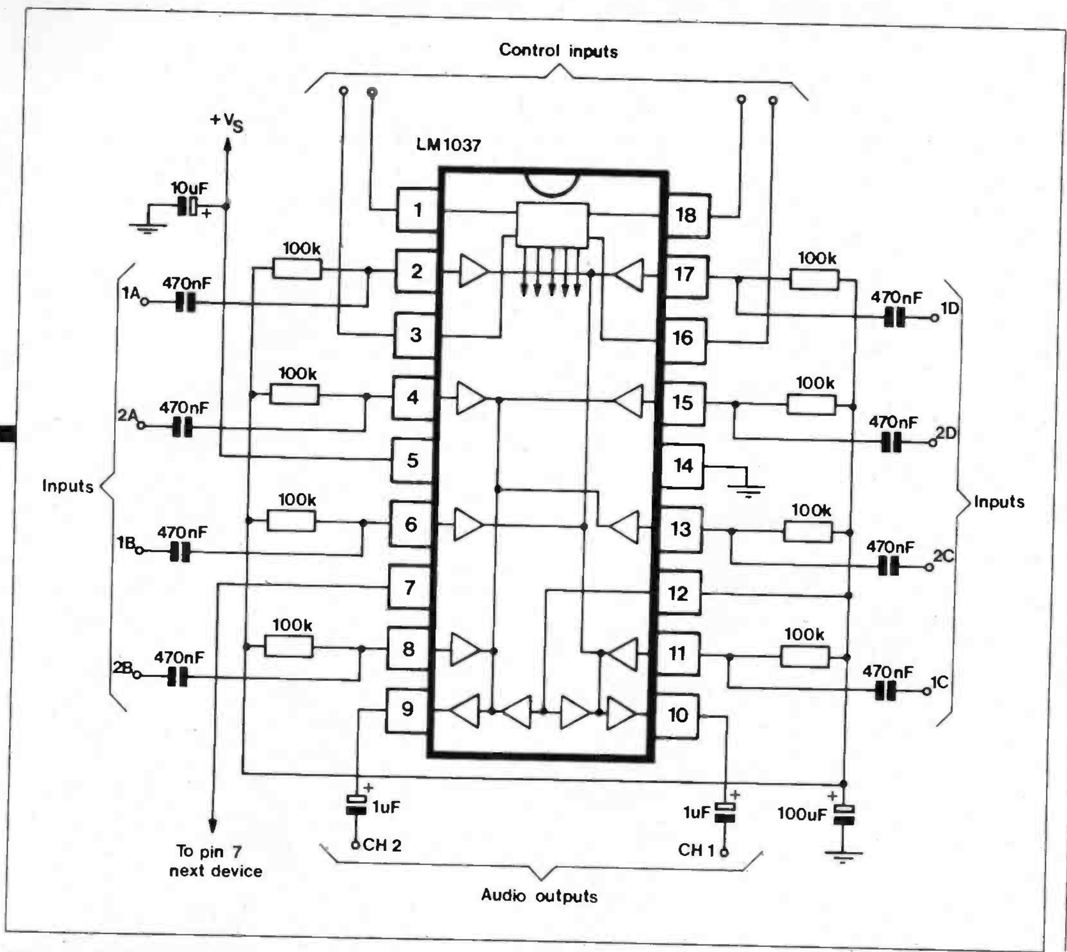


Figure 1. IC Pinout Diagram.

pins (pin 7) of the devices together and connecting the two pairs of output pins (pin 9 and pin 10) in parallel. It should be noted that only one output capacitor is required for each channel.

Input signals should be limited to approximately 2.5V RMS (for a 12V power supply) to avoid excessive distortion. The maximum instantaneous voltage between the two inputs of any one channel is 9.6V; voltages in excess of this value may cause degraded channel separation or increased distortion. It should be noted that the maximum signal handling is dependant on the power supply voltage (at higher supply voltages the device is capable of handling larger signals).

IC Power Supply Requirements

The LM1037 will operate over a wide range of power supply voltages between approximately 8V and 28V. IC current drain is typically

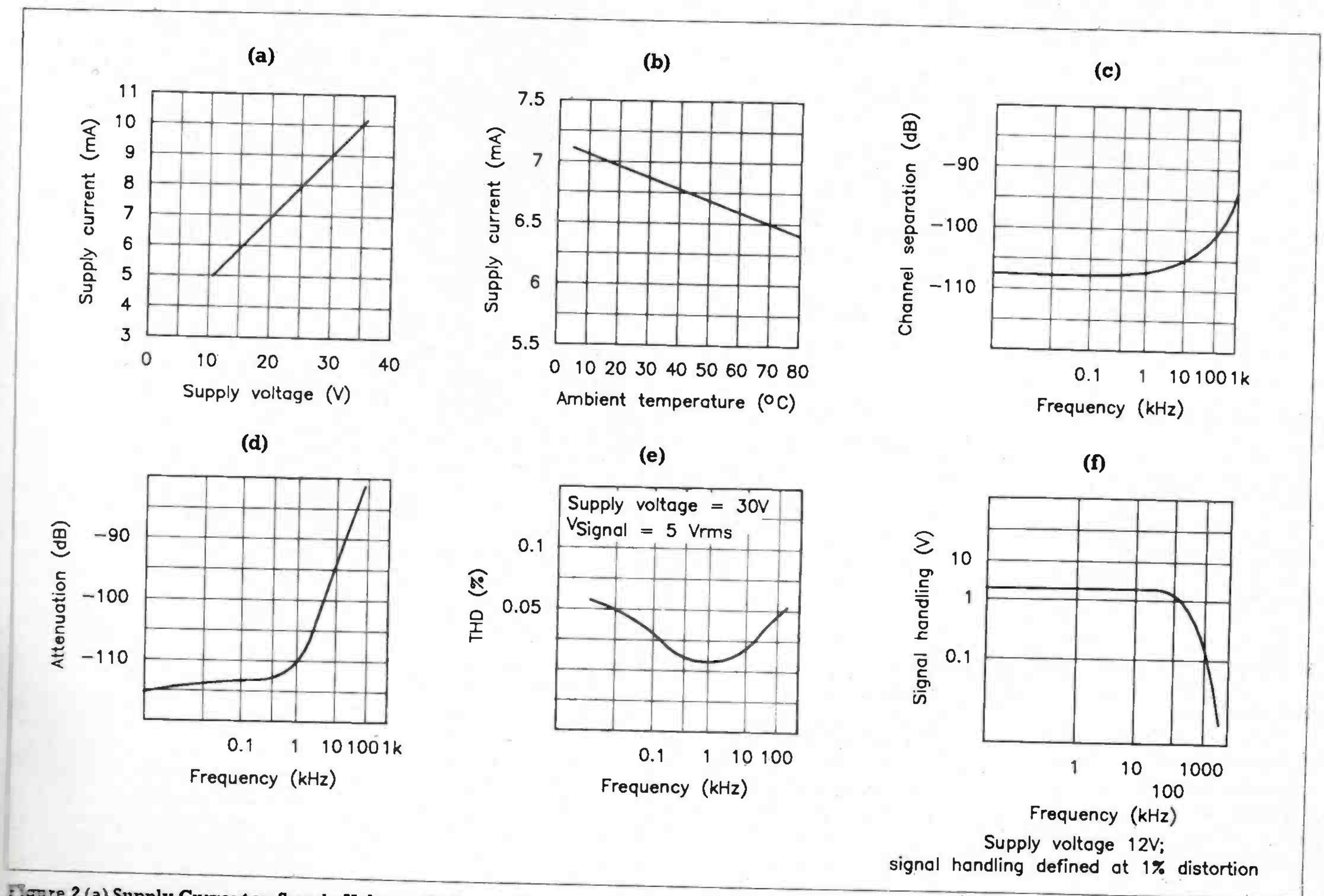


Figure 2 (a) Supply Current vs Supply Voltage, (b) Supply Current vs Temperature, (c) Channel Separation vs Frequency, (d) Attenuation of Unselected Inputs vs Frequency, (e) THD vs Frequency, (f) Signal Handling vs Frequency.

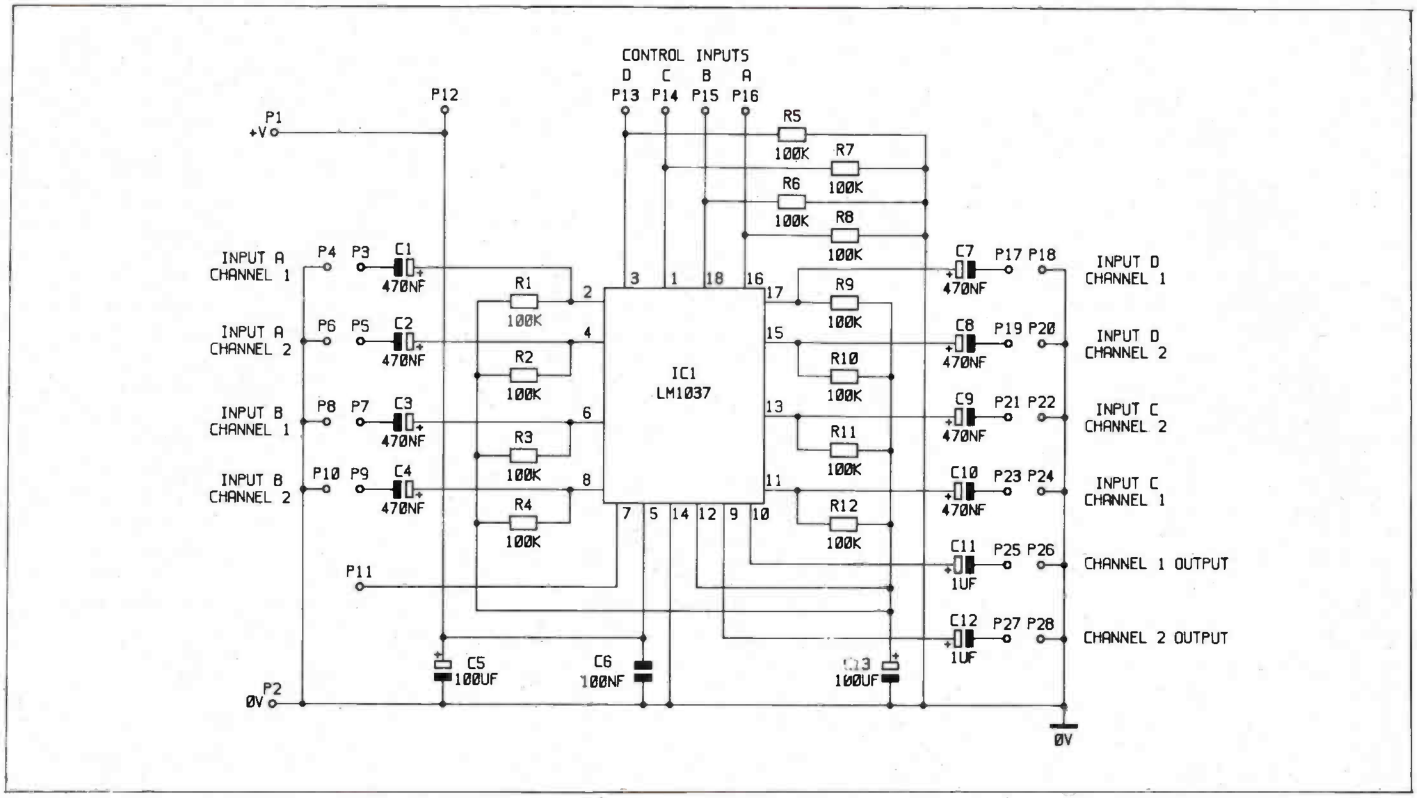


Figure 3. Circuit Diagram.

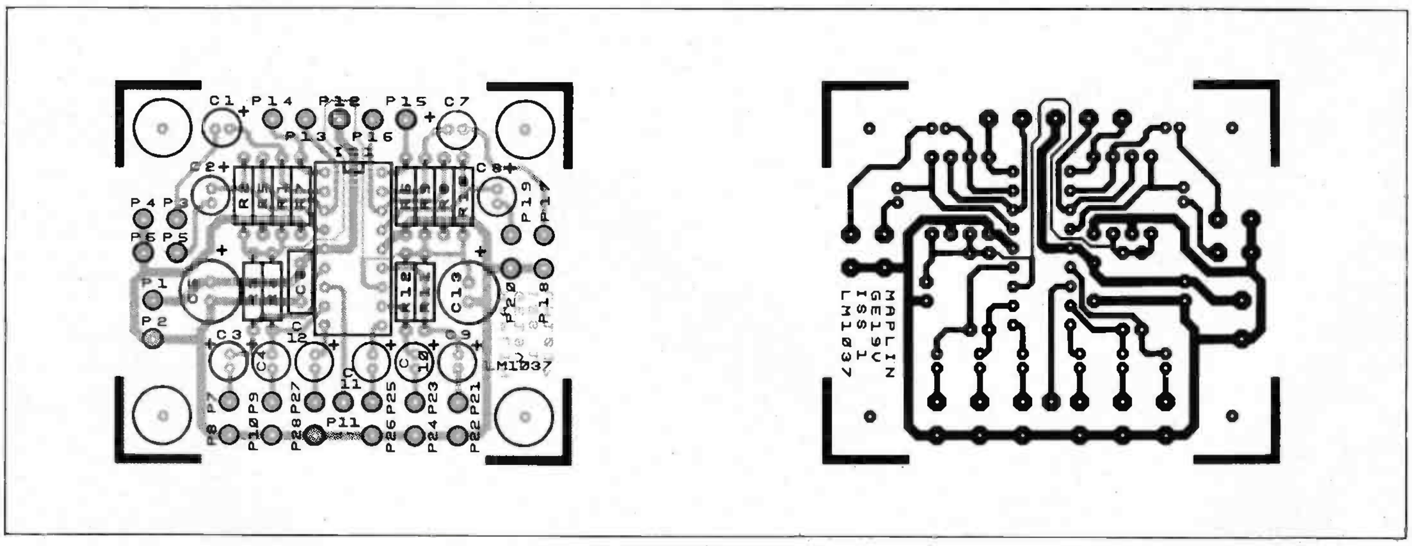


Figure 4. PCB Layout.

around 6mA at 12V. It is necessary to decouple the supply rail close to the IC to avoid the introduction of excessive noise and to prevent possible instability.

Printed Circuit Board

A high quality fibre-glass PCB with printed legend is available for the basic LM1037 four channel stereo source selector circuit. Figure 3 shows the circuit diagram and Figure 4 shows the PCB layout. A single supply of between 8V and 28V is required to power the circuit. The power supply should be capable of delivering at least 15mA and should be adequately decoupled to prevent the introduction of mains derived noise onto the supply rail. Power supply connections are made to P1(+V) and P2(0V). All connections are illustrated in Figure 5. Channel selection is achieved by applying a DC voltage of between 2V and 50V to P13, P14, P15 or P16 as appropriate (refer to Table 2). Access to the mute inhibit line is provided by P11. Finally Table 3 shows the specification for the prototype circuit built using the PCB.

	Inputs Switched to Output Pins							
Input Channel	1A	2A	1B	2B	1C	2C	1D	2D
Pin Number	P3	P5	P7	P9	P23	P21	P17	P19
Control Pins P13	Low	Low	Low	Low	Low	Low	High	High
P14	Low	Low	Low	Low	High	High	Low	Low
P15	Low	Low	High	High	Low	Low	Low	Low
P16	High	High	Low	Low	Low	Low	Low	Low
Output Pin	P25	P27	P25	P27	P25	P27	P25	P27
Output Channel	1	2	1	2	1	2	1	2

Table 2. Truth Table for LM1037 Module.

Supply Voltage Range	8V – 18V
Supply Current (12V)	5.5mA
Maximum Input Voltage (12V supply)	3V RMS
Voltage Gain	0dB
THD (Input voltage = 770mV RMS at 1kHz)	0.02%

Table 3. Specification of Prototype (built using the PCB).

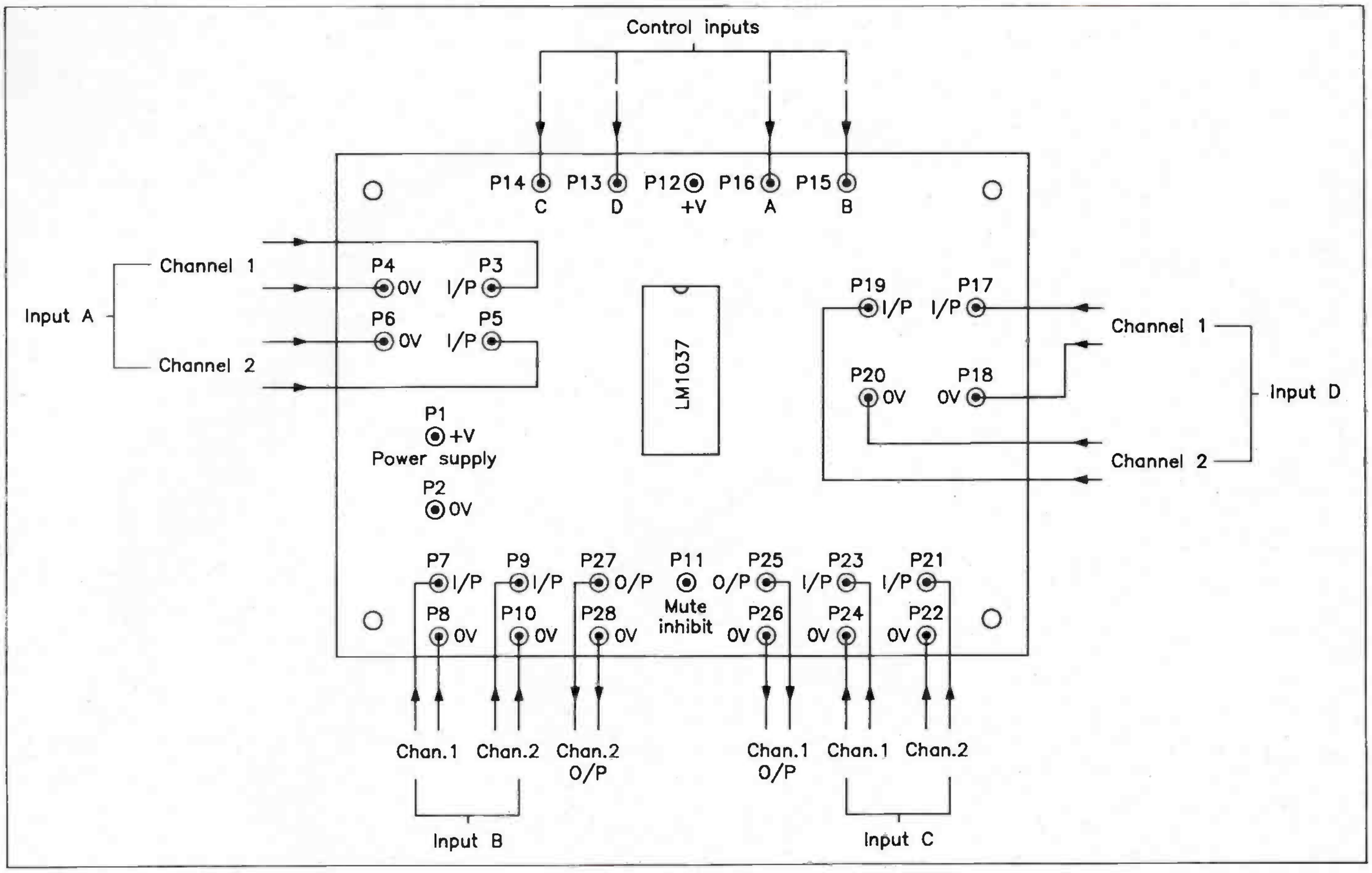


Figure 5. Wiring Diagram.

LM1037 PARTS LIST

Resistors: All 1% 0.6W Metal Film			
R1-12	100k	12	(M100K)
Capacitors			
C1-4, 7-10	470nF 100V PC Electrolytic	8	(FF00A)
C5,13	100μF 35V PC Electrolytic	2	(JL19V)
C6	100nF Disc	1	(BX03D)
C11,12	1μF 100V PC Electrolytic	2	(FF01B)
Semiconductors			
IC1	LM1037N	1	(QY33L)
Miscellaneous			
	Constructors Guide	1	(XH79L)
	PC Board	1	(GE19V)
	DIL Socket 18 Pin	1	(HQ76H)
	Pins 2145	1 Pkt	(FL24B)

The above items are available, in a kit:
Order As LP06G (LM1037 Kit) Price £7.95
The following item is also available separately:
LM1037 PCB **Order As GE19V Price £1.95**

'Hello Who's Calling?'

by J.K. Hearfield Part 7

Modern Telephones

Telephones have come a long way since the days of Alexander Graham Bell. Gone are the ornate cases and the complex and delicate transducers. Today's telephones can't seem to make up their minds whether they are toys or tools (though in fact, of course, they can be either, or both). But if you were to open one up and look inside, you would see ICs and passive components mounted on a printed-circuit board, like a cheap radio. A telephone today is just another electronics product.

The world-wide telephone market is so huge – believe it or not, there are now almost three-quarters of a billion telephones out there – that semiconductor manufacturers have found it worth their while to produce several devices tailored to the need of telephone designers. The giants of the industry – Philips, Motorola, Texas and so on – all market a range of telecommunications products. Some companies have even specialised in particular small market segments, such as dialler ICs or loudspeaking telephone devices. Because it's cheaper to use these devices than not to, telephone design has over the last few years settled down into choosing whose ICs to use for each function, and then making the product meet the relevant standards.

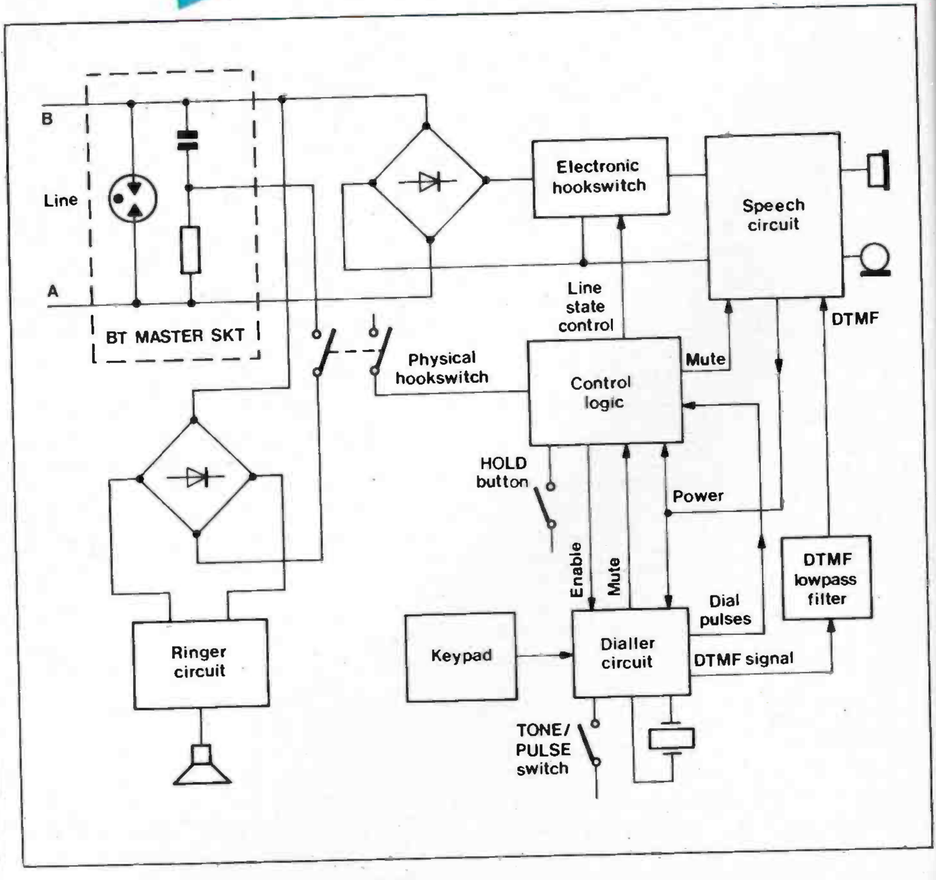


Figure 1. The elements of a modern telephone.

Packaging too has changed to reflect the changing perception of what a telephone is for. Some instruments look really impressive, with rows of buttons and coloured lights. Others are simply for fun. The Mickey Mouse 'phone is a plastic model of the character in full colour, complete with ears and delighted grin. When BT first marketed this product, plug-in telephones still used the large and unsightly four-way jack plug, so to hide this plug, the plastic moulding included an orifice in the most suitable place: at the back, just below the tail.

Functional Overview

The block diagram of Figure 1 illustrates how the major functional blocks of a telephone fit together.

An incoming call is signalled by the presence of 'ringing current' on the line Despite its name, this consists of a large ac voltage (some tens of volts rms) with enough energy to activate an electromechanical bell. The ringer circuit converts this energy into a calling signal that drives a loudspeaker or acoustic sounder.

The call is answered by lifting the handset or pressing an 'answer' key. Instead of using a cradle switch (operated by lifting the handset) to make and break the line directly, modern practice is to use an electronic hookswitch driven by the telephone control logic. Since this hookswitch can be opened and closed rapidly, it can also be made to do the job of the dial contacts on a conventional telephone.

Once the call is answered, the telephone must provide a means of coupling speech energy to and from the line whilst at the same time minimising sidetone. Also, the line must be correctly terminated in the impedance that maximises power transfer. These tasks, and others, are handled by the speech circuit.

Finally, the telephone must (usually) also be capable of making outgoing calls, so it must include a means of signalling the desired number to the exchange. The signals may be pulses, or tones, or a combination of both. The dialler circuit takes care of this, injecting its signals either into the speech circuit or (via the control logic) into the electronic hookswitch.

BT Master Socket

Plug-in telephones are quite a recent innovation in the UK. Prior to 1984, life was simple: BT owned the external wiring, the internal wiring and the telephone. But once people were allowed to buy telephones from whoever they chose and put them wherever they liked, it became necessary to define the physical point at which BT's responsibility ended and that of the telephone owners began. This boundary point is the Master Socket, sometimes know as the Master Jack. It contains a 6-way connector, deliberately chosen to be different from the one used by the US telephone system; a blocking capacitor, a resistor, and some protection (though not much) in case the external cable is struck by lightning.

Taking the Mickey out of telephones?

The A and B wires from the exchange pass straight through the Master Socket to the telephone (see Figure 1). An earth wire, if fitted, does the same. Across A and B are connected a gas discharge tube, intended to limit the size of any voltage surge that might be induced onto the line by a nearby lightning strike, and a series capacitor and resistor. The capacitor (1.8µF) is there primarily to provide dc isolation for the ringer circuit.

Ringer

The ringer circuit in a modern telephone operates on quite a different principle to that of an electromechanical bell. Instead of using the incoming ring signal to move a piece of metal, today's telephones use the energy in the ring signal to drive an audio power oscillator. The function performed is the same, but at lower cost, in a fraction of the space, and much more reliably.

Ringer IC

As Figure 2 shows, a typical ringer device consists of an oscillator and a power amplifier. To make the calling signal sound a little more interesting and distinctive, two oscillators are often used. A low-frequency oscillator running at about 10Hz switches the frequency of a high-frequency oscillator between its two possible values of typically 650Hz and 800Hz to produce the characteristic warbling sound. This signal is amplified and fed either to a loudspeaker or to an acoustic transducer. If a transducer is used, the oscillator is usually tuned to produce signals at or near its resonant frequency. A loudspeaker and its associated transformer (or blocking capacitor) is a more expensive solution, but gives the designer freedom to add other features. For example, the user could be allowed to hear the DTMF digits as they go out, or the various tones on the line.

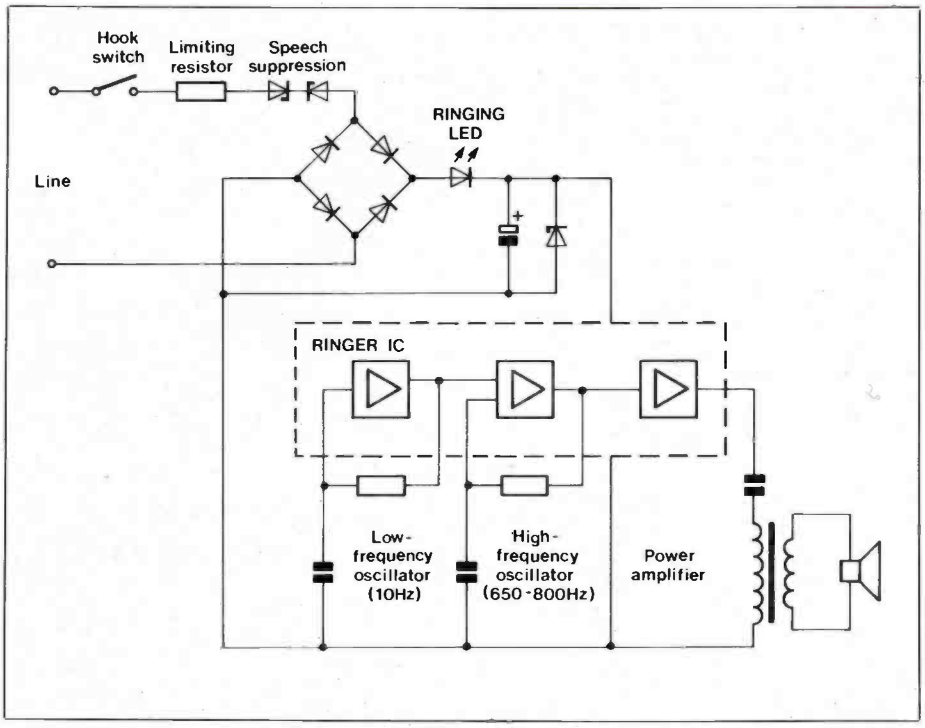


Figure 2. A typical ring detection circuit.

Powering the Ringer

The ringer should operate only whilst the exchange is applying ringing current to the line. Ringing current is usually a large ac voltage (75V rms, or more) at a very low frequency (probably 25Hz). This ac voltage must be converted into a dc voltage to power the ringer IC.

The exchange constantly maintains a dc voltage across the line, and monitors the line looking for the current flow that would indicate that the telephone had gone off-hook preparatory to making an outgoing call. The ringer must ignore this dc voltage, and so it must be isolated from the line by a large capacitor. Fortunately, a suitable capacitor is built into the BT Master Socket, so there is no need to put another inside the telephone. The ac-to-dc conversion is done by a straightforward bridge rectifier and smoothing capacitor.

A number of factors must be borne in mind when designing the circuit connecting the line to the ringer. First, the ringer IC supply voltage must be kept within safe limits. A suitable zener diode and limiting resistor take care of this. Second, a visual indication of incoming ringing is normally provided, since the user has the option of switching the tone caller off. Some designers use a neon (fed from a voltage multiplier) though most prefer a LED. The LED must obviously be chosen to handle the wide range of current levels that will occur in this application.

Two other points are perhaps less obvious. Ringing should stop at the instant the user answers the call, and the ringer should not confuse outgoing dial pulses (or speech) with incoming ringing. The usual solutions are to include a physical hookswitch in series with the ringer, and if the telephone is designed to allow on-hook dialling, to include also a pair of back-to-back zeners. These effectively cause small voltages on the line to be ignored.

Electronic Hookswitch

The hookswitch circuit of Figure 3 is

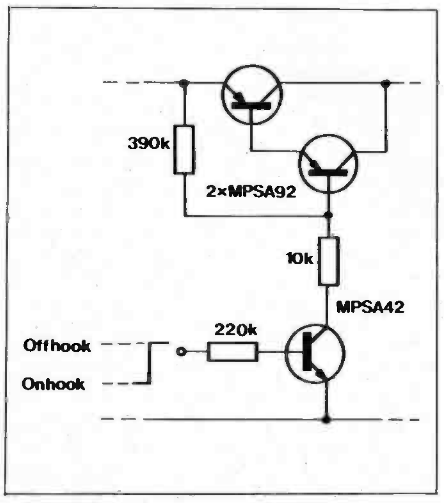


Figure 3. The hookswitch is often realised like this.

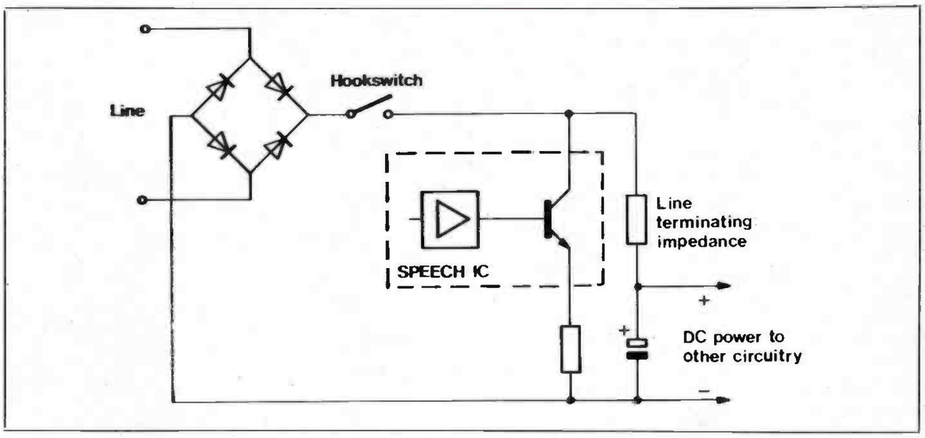


Figure 4. Line impedance matching and power extraction.

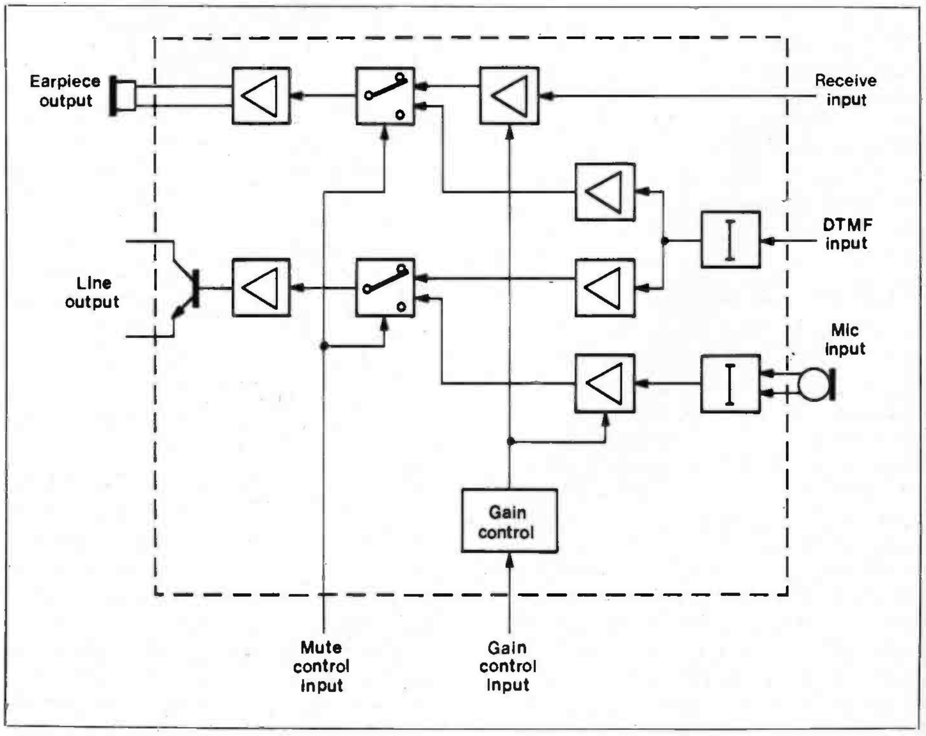


Figure 5. Block diagram of speech IC (simplified).

typical. The pnp darlington pair is turned on by the npn device, which in turn is controlled directly by a low-level signal from the control logic circuit. The worst-case stress on the transistors is surprisingly large. A telephone on a short line might experience a peak line voltage as high as 200V during ringing, and have to carry 100mA during a call. Special high voltage transistors are therefore used in this circuit.

Separating the physical and function aspects of the hookswitch has other benefits too. Many telephones now have a 'Hold' feature. This can be achieved in essence by muting the speech circuit whilst leaving the electronic hookswitch closed. It makes no difference then whether the user replaces the handset or not.

Line Impedance Matching

It is important to transfer maximum audio power in and out of the telephone, so the designer must carefully control the impedance the telephone presents to line. This is often done by supplying one fixed impedance defined by passive components and ensuring that all other shunt paths are too large to matter. It is no longer enough to pretend that a line looks like a 600 ohm resistor. In the UK at least, the line matching impedance is a complex network.

Figure 4 illustrates one way of terminating the line. With the hookswitch closed, the diodes in the bridge are forward-biased, and the impedance seen looking into the telephone is the line terminating impedance in series with the negligibly small impedance of the smoothing capacitor. The uncommitted transistor built into the speech IC is just a current source sitting across the line, and as such does not affect the impedance.

Speech Paths

Figure 5 shows the audio paths through a typical speech IC. As the diagram shows, the 'Receive' path (from line to the earpiece) is quite separate from the 'Transmit' path (microphone to line). It is up to the telephone designer to arrange for some means of side tone cancellation; how this is done is described a little later.

The 'Receive' signal input (derived from the incoming signal) passes through a couple of amplifier stages and a switch, and drives the earpiece directly. The 'Transmit' signal from the microphone is similarly amplified, and drives an uncommitted transistor. Signal is injected into the line by connecting the transistor across it.

The speech IC has two other inputs, labelled 'Mute' and 'DTMF input'. The Mute signal isolates the microphone circuit from line during dialling, and at the same time feeds DTMF signals both to line and (at a lower level) to the earpiece, as confirmation that the dialler is working. Some telephones also include a separate Mute button, and this either activates the speech IC Mute input or more simply just short-circuits the microphone. (Open-circuiting the microphone is not usually a good idea, for stability reasons).

The speech IC also possesses a 'Gain control' input. The 00-type telephone made some attempt to compensate for different line lengths by incorporating a simple regulator circuit based on the use of forward-biased diodes acting as shunts across the microphone and earpiece. Today's telephones are a little more sophisticated. An amplifier in each speech path ('Transmit' and 'Receive') is designed to have its gain controlled by an external dc voltage. The voltage is conveniently derived by inserting a small resistor in series with the line and sensing line current, because a low value of line current implies that the line resistance (and hence its ac loss) is high. It is normally possible too to adjust the gain of an amplifier in each path to compensate for transducers of differing sensitivity.

Sidetone Balancing

The problem of sidetone removal – that is, of preventing the signals fed in to the microphone from appearing in the earpiece – faces every telephone designer. Figure 6 illustrates one way of solving it by means of a wheatstone bridge arrangement.

Signals from the microphone amplifier are split between the line impedance and a (small) resistor. Provided the ratio between the line impedance and the balance network is the same as that between the other two resistors, no signal is passed directly from the microphone to the earpiece. The impedance of a 'typical' line can be modelled as shown in the re-drawn bridge circuit of Figure 6(b), and whilst no real line has an impedance exactly like this, in practice the levels of sidetone achieved are acceptable.

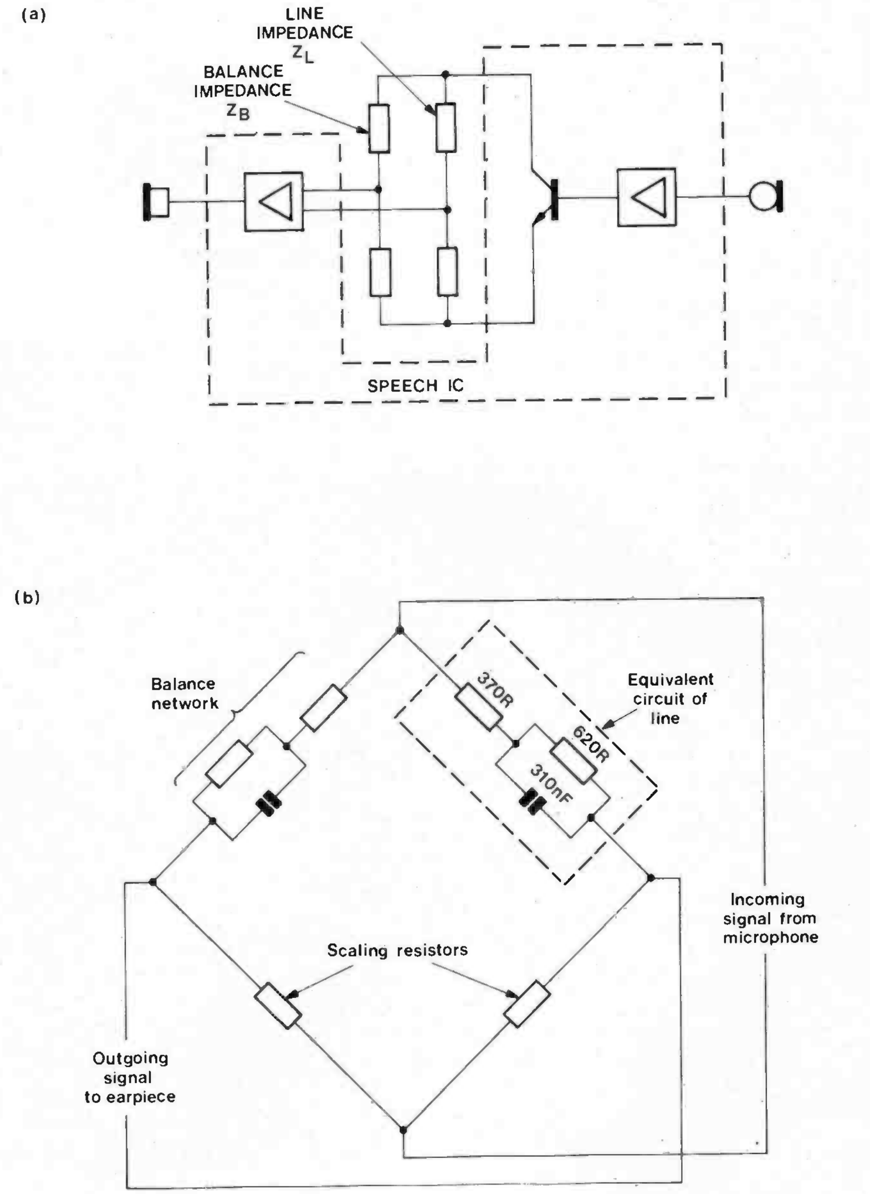


Figure 6. Sidetone balancing by means of a wheatstone bridge.

Power Extraction

All the electronics must be powered from somewhere, of course. Mains power adaptors are expensive and often inconvenient to use, whilst batteries must be replaced from time to time. By far the best option is to take power from the line. The limitations of this approach – that the current drain must be kept below a few milliamps when the telephone is in use, and a few tens of microamps when it is not – are easily met in practice. Circuitry that is used when the telephone is on-hook, such as the dialler memory, is CMOS-based and powered (through a resistor of at least 10 Megohms) from the line side of the electronic hookswitch.

The circuit of Figure 4 is commonly used to extract power from the line when the telephone is off-hook. The diode bridge ensures that the supply voltage polarity is correct, even if a jointer has inadvertently reversed the A and B wires somewhere. The supply is smoothed by the resistor in the line terminating impedance in conjunction with the electrolytic. This capacitor, incidentally, must be large enough to supply other circuitry during short line breaks, such as dial pulses. It is normal practice too to add a 5 volt zener diode across the capacitor to limit the internal supply voltage to a safe value.

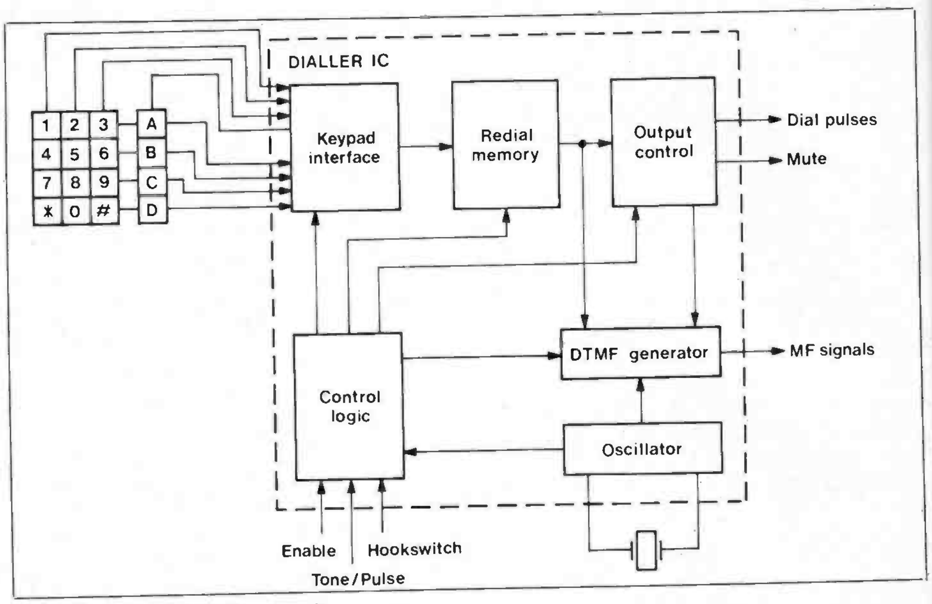


Figure 7. A typical dialler circuit.

Dial Pulse and MF Outputs

Signalling to the exchange at 10 pulses per second was the last word in technology in 1912, when the Epsom exchange was brought into service. More than 75 years later, most public exchanges in the UK are still incapable of accepting signals faster than this.

Modern multifunction telephone.

Dialler Circuit

The old-style electromechanical rotary dial was unsatisfactory in many ways. It was difficult and expensive to manufacture; it was unreliable; and over several years of use its key parameters drifted so much that exchanges had to be designed to cope with signalling timings as much as 30% away from their nominal values. A modern telephone suffers from none of these problems. Instead of a dial, it has a keypad and a dialler IC, see Figure 7.

Yet there is an alternative. It's called DTMF – Dual Tone Multi-Frequency signalling. A DTMF signal consists of two sinewaves of different frequencies, added together. Eight different frequencies are used, arranged as 2 groups of 4 (see Table 1) to give 16 possible different combinations and hence 16 possible different DTMF 'digits'.

The beauty of this system is its speed. The DTMF receiver at the exchange has only got to decide which two frequencies are present in a digit, a task that takes less than 50msec. Sending the same information at 10 pulses per second could take anywhere between 1000 and 2000msec per digit.

MF Filter

The DTMF output produced by the dialler IC comes directly from a digital-to-analogue converter, and so consists of a staircase-like approximation to the desired waveform (see Figure 8). In other words, the signal contains unwanted high-frequency energy as well as the two MF signals. Most telephone companies (including BT) insist that this high-frequency ripple be removed before the signals leave the telephone, and a simple second-order Sallen & Key filter like that of Figure 8 is often used to get rid of it. The use of an emitter follower in place of the more conventional op-amp may seem surprising, but the circuit works very well.

Keypad

Though it is of course quite feasible to equip a telephone with a set of discrete keys, like a computer keyboard, it is far cheaper not to, and most modern instruments employ a membrane keypad. The principle is straightforward: pushing a key moves a small piece of conducting material into contact with two separate tracks on a PCB, shorting them together. The return spring consists of a piece of moulded rubber, which is distorted out of shape when the button is pressed. The PCB tracks are often gold-plated to ensure that any corrosion from atmospheric pollutants does not increase the contact resistance too much.

The keypad switches are invariably arranged as a matrix, as shown in Figure 9(a), to minimise the number of pins needed by the dialler IC. Many modern telephones are designed for use with PABXs as well as on direct exchange lines, so it is common to see keypads equipped with "★" and "£" in addition to the ten numeric keys.

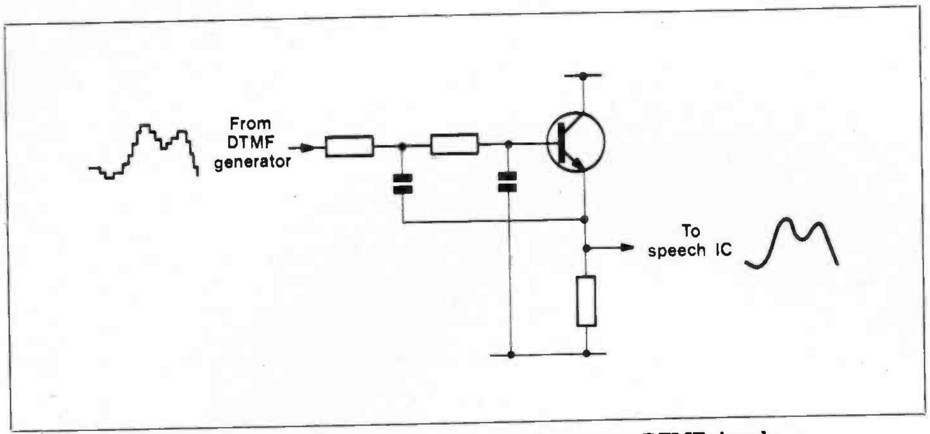


Figure 8. This simple lowpass filter is usually adequate to clean up DTMF signals.

Memory

Even the simplest and cheapest modern telephones now commonly offer a 'Last Number Redial' feature. Everyone knows how irritating it is to look up a number, key it in, and then get busy tone. Five minutes later you have to go through the same process all over again. It's much more convenient to simply press the 'redial' button and let the electronics do the work. Of course, the redial feature works because the last number dialled is stored in the telephone's memory (actually, in the dialler IC's memory) until a new number is dialled. This means, incidentally, that you can always find out who was called by the last person to use a particular telephone equipped with this feature, even if you were out of the room when the call was placed. Just press 'Redial', and see who answers the call...

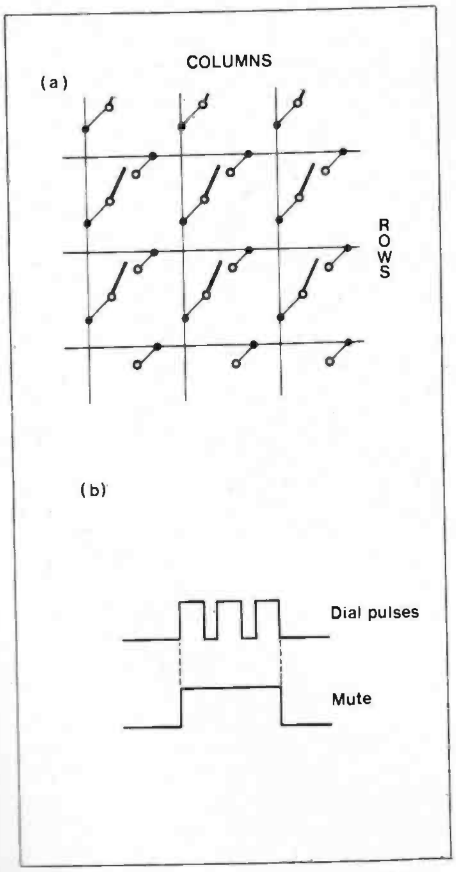


Figure 9. (a) Keypad switches arranged in a matrix. (b) The mute output provides a blanking pulse during dialling.

Timing

There is no real need for dial pulses to be generated with a precisely defined repetition rate and mark-space ratio. A 5% tolerance is quite acceptable. DTMF signals are rather more tightly specified: the frequency transmitted must be no more than 1.5% away from the nominal frequencies listed in Table 1.

The DTMF signals are normally generated by straight digital division of a master clock running at several megahertz. But since the nominal frequencies were carefully chosen so that they are not harmonics or sub-harmonics of each other, it is almost impossible to generate them precisely. For example, to get 697Hz from 3.58MHz would require a division ratio of 5136. Choosing 5120 (to keep the division logic reasonably simple) yields an actual frequency of 699.1Hz, an error of 0.3%. The error doesn't matter, provided the frequency always stays within 1% or so of 699Hz. But this level of stability demands a crystal-controlled master clock. A frequency of 3.58MHz is invariably used, because this is the colour-burst frequency used in the US television system, and so crystals are cheap and easy to get.

Mute

The choice of the DTMF frequencies was not capricious or arbitrary. Research revealed that these particular frequencies are less likely than others to appear in human voices. Since two such unlikely tones must be simultaneously present in a DTMF digit, it seems improbable that an exchange DTMF detector circuit could mistake speech for a DTMF signal. But to make absolutely sure it never happens, telephones are designed to prevent speech from being passed to line during DTMF signalling. Dialler ICs normally have a 'Mute' pin, which provides a blanking signal to shut down the speech IC during dialling, as shown in Figure 9(b). The Mute signal also prevents the telephone user from hearing clicks in the earpiece during dial pulsing.

The latest style standard telephone.

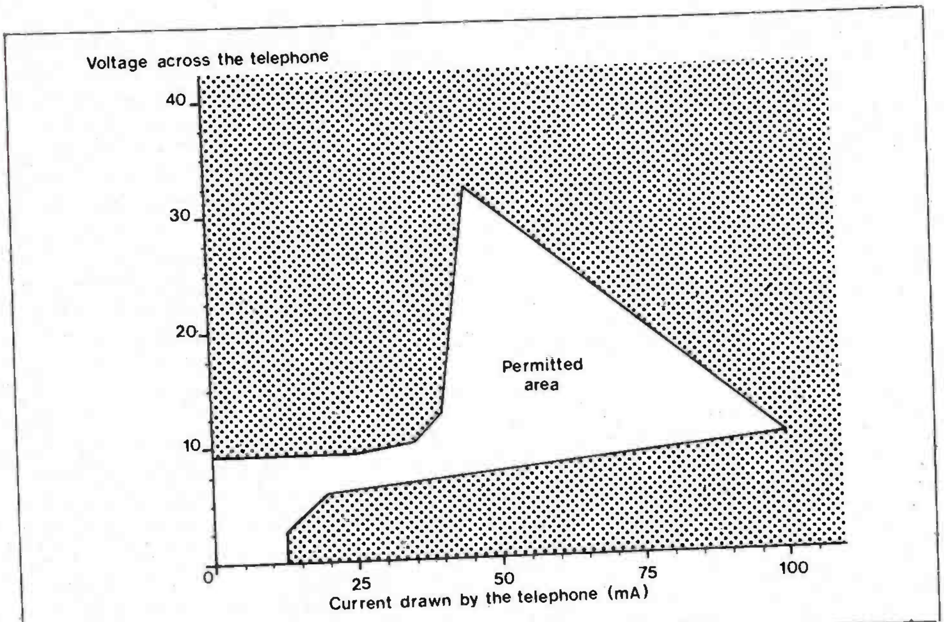


Figure 10. The voltage and current in the telephone must always be inside the dc mask.

Recall

Telephones intended for use with PABXs need to be able to send one additional signal. Modern PABXs are always designed to accept DTMF signals from their extensions. The incoming digits are received and processed in special circuits called MF (or DTMF) receivers, or MFRs. Because an MFR is an expensive item, and plays such a small part in the duration of a call, a PABX is generally equipped with only a few of them. When an extension goes off-hook, the PABX allocates it an MFR, and when dialling is complete the MFR is freed to wait for another caller. But if an extension user wishes to instruct the PABX to perform some action during a call – for instance, to call back when another extension becomes free – there is no way to do so, because the MFR is no longer there. To get round this problem, extension telephones are fitted with a special button – the 'Recall' button. Pressing it connects a free MFR to the extension. PABXs differ in the recall signal they need; some types look for a precisely-timed break in line current, whilst others expect an earth on one wire of the pair. To cope with both, extension telephones commonly have a discreetly placed switch labelled 'TB/ER' for Timed Break/Earth Recall.

Standards

Gaining approval to sell a telephone in the UK can be a difficult and protracted business, even though the requirements to be met are (for the most part) clearly spelt out in British Standards.

It is not enough to design a telephone that works. Any telephone that could be connected to the UK public telephone network must first be exhaustively tested to ensure that it meets the required standards. The tests cover virtually every aspect of a telephone's performance: ringing sensitivity, impedance, speech sensitivity, dialling, DTMF levels, and so on. And because a telephone by its very nature can inject voltages into the public telecommunications network (unlike the case of, say, a fridge and the public main supply network) it must also be tested to make certain it is safe. Not necessarily safe to use, but safe in that it cannot harm BT employees working on the network.

It must be emphasized that connecting any unapproved circuitry to the public telephone network is illegal, and might even hurt someone.

Examples

There is no space in a short article (nor, in fact, in quite a long one) to cover all the relevant standards, explain what they mean, and describe how to meet them. But to give a flavour of how the standards work, a couple of the less obvious ones are discussed here.

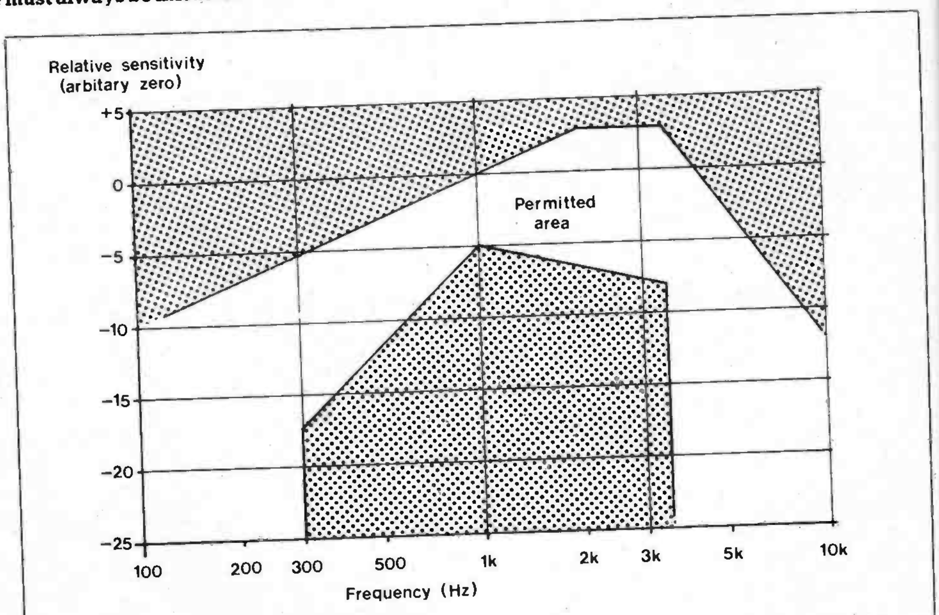


Figure 11. The telephone sensitivity must lie within these limits for a zero-length line.

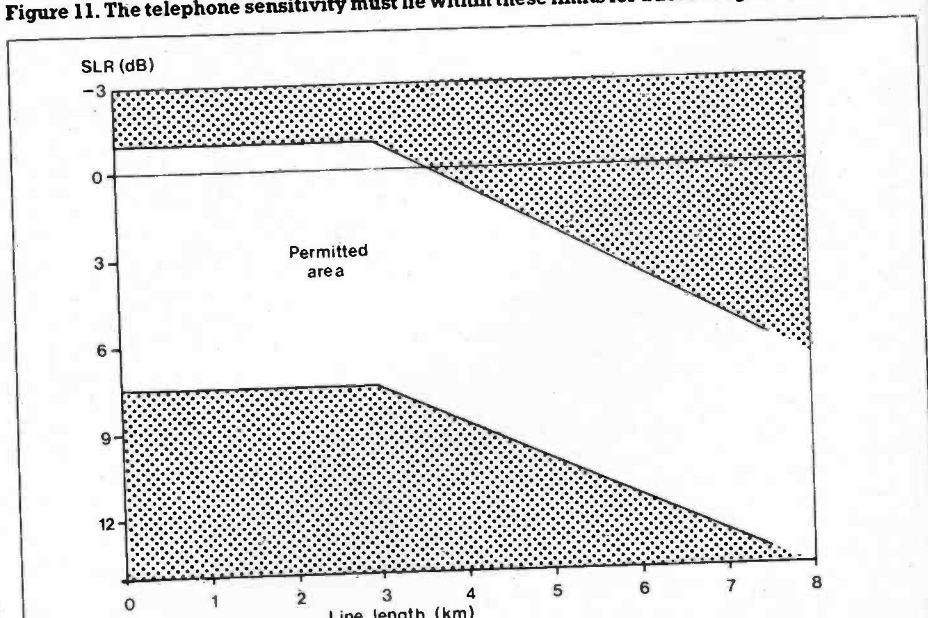


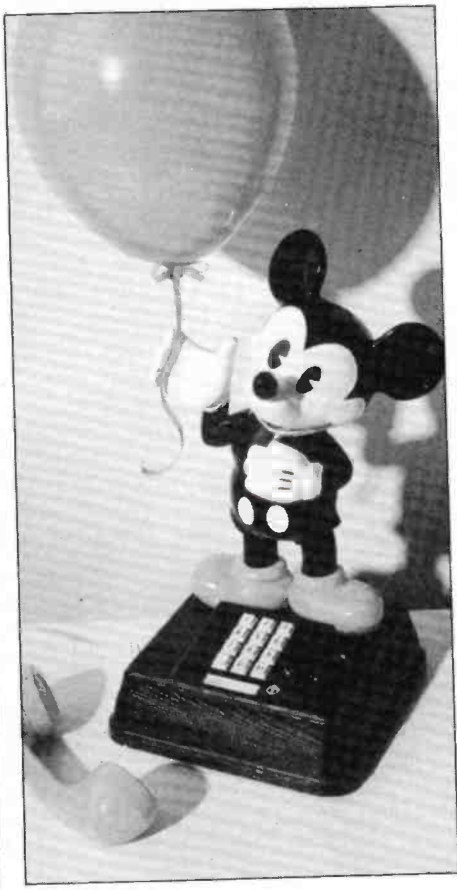
Figure 12. The send loudness rating (SLR) must be between specified limits.

1	2	3	A	697
4	5	6	B	770
7	8	9	C	852
★	0	£	D	941
1209	1336	1477	1633	Hz

Table 1. DTMF signal frequencies.

The dc characteristics of the telephone must lie within a performance envelope known as the dc mask (Figure 10). This ensures that the telephone will be compatible both with exchanges that power the line from a (nominally) 48 volt battery in series with a 400 ohm feeding bridge, as well as with more modern exchanges that supply a constant-current feed to the line. The telephone must obviously be designed in such a way that the exchange can detect whether or not it is off-hook.

Sensitivity – that is, frequency response – is specified at several different line lengths by a family of graphs like Figure 11. Send sensitivity and receive sensitivity are each specified separately. At first sight, the performance required seems quite easy to achieve, especially since the graph defines only the relative sensitivities at each frequency. (In other words, the 0dB point is arbitrary: it can represent 10mV or 100mV or any other voltage). However, what is being assessed here is the acoustic performance of the complete telephone. Testing is carried out with the telephone connected via an artificial line to a feeding bridge similar to that found in a real exchange.



The overall acoustic performance of a telephone is assessed in terms of loudness ratings (Figure 12). The Send, Receive and Sidetone loudness ratings must all lie within prescribed limits. Loudness ratings are computed from sensitivity measurements by means of a complex formula that takes into account the frequency and line length used, and applies different weighting factors at each frequency. The sensitivity must be measured at each of 8 different lengths of (artificial) line, and for each line length, at each of 14 frequencies. The resulting curves give some idea of how the telephone will probably behave when human beings use it to talk to each other.

And that, ultimately, is what all the technology is there for: so that you can call your mum to wish her a happy birthday.

Lament of the Engineer's Wife continued from page 23.

Christmas (see Figure 4), when all they want to do is plug in the cheap-and-cheerful bottom-of-the-range tape player from Curry's and actually listen to Madonna or Elton John? With great fortitude, our children have unwrapped car kits, knitting kits, Maplin watch kits, aeroplane kits, electronics-for-twelve-year-old-kids kits, make-your-own-basket kits. We nearly subjected them to a build-your-own radio control car kit. Thank goodness a business trip to Hong Kong included a visit to a toy shop, so impulse-buying saved hours of sharing the soldering irons and searching for dry joints.

Figure 4. Technical presents.

We all know that whenever small children go into the bathroom, time and reality have no further meaning for them. Why does the same apply when the engineer goes into his lab? How many family-hours are wasted (see Figure 5) whilst we wait for:

"I just want to try this mod." "I just want to measure this." "I just want to write this down."

And dinner goes cold at our friends' house, or the library is closed when we get there, or we have missed the train or the last post, or it's one o'clock in the morning *again* and why aren't we asleep?

However, I must confess that this last bit is catching. I just wanted to write this down, so the family is patiently waiting for dinner, clean clothes for tomorrow, and an early night. In that order. Engineers know that a woman's place is in the kitchen, so I must be off.

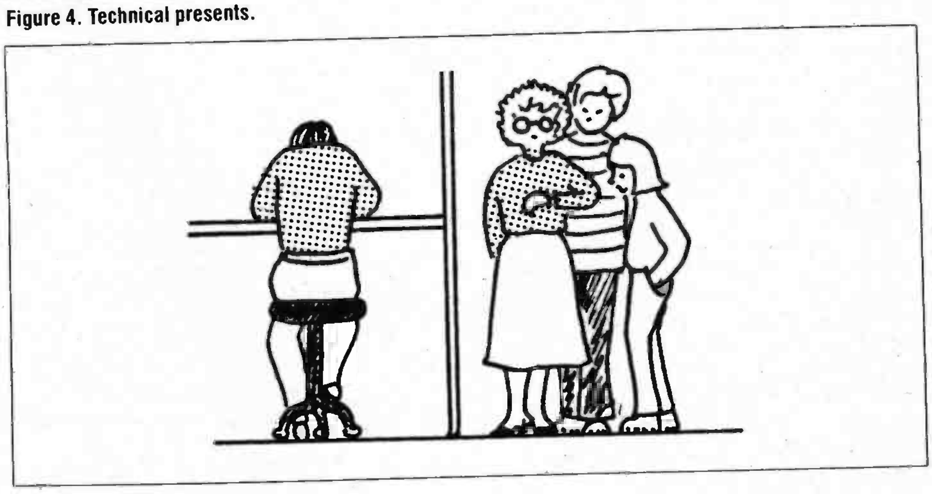


Figure 5. Why are we waiting?

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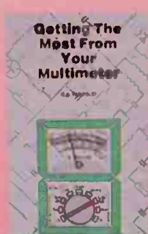

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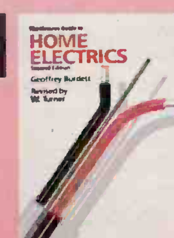

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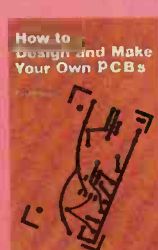

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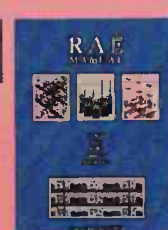

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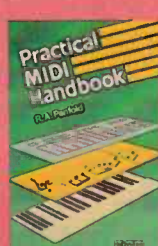

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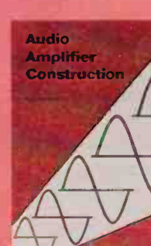

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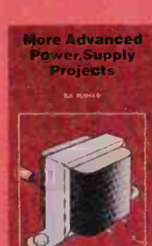

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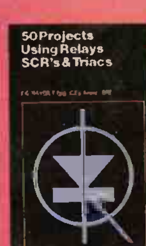

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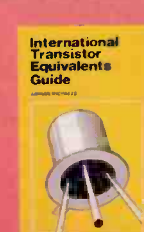


International Transistor Equivalents Guide, by Adrian Michaels. *(WG30H) Cat. P78.* Previous Position: New Entry. **Price £3.50**

Midi 8 Way Thru' Box

By Joe Fuller

★ **Opto Isolated**
★ **Eight Independently Buffered Outputs**
★ **MIDI Data Indicator**
★ **Integral Power Supply**
★ **Ideal for use with Sequencers and Master Keyboards**
★ **Overcomes Problems Caused by 'Chaining'**

Introduction

Over the last few years, there has been a large increase in the number of affordable electronic musical instruments on the market; such as synthesisers and drum machines. This has brought high quality equipment within the reach of amateur and semi-professional musicians. Gone are the days it seems, when the average keyboard player had one electric stage piano. Now, many keyboard players have multi-synthesiser set-ups, with a plethora of expander boxes, samplers and electronic effects units. All of which are connected via the ubiquitous MIDI. The MIDI system (Musical Instrument Digital Interface), is an interface standard adopted by most manufacturers of electronic musical instruments. MIDI enables control information to be sent, for example, between one synthesiser and another, this allows the two synthesisers to be played from one keyboard. The idea of linking synthesisers together need not be limited to just two synthesisers, the sky is the limit (or rather your bank overdraft!). Figure 1 shows how three synthesisers may be chained together and operated by one 'Master Keyboard'. The MIDI OUTPUT from the Master Keyboard is connected to the MIDI INPUT; of Synthesiser A, the MIDI THRU' of Synthesiser A is connected to the MIDI INPUT of Synthesiser B, and so on. The MIDI THRU' is an output socket that duplicates the signal appearing at the MIDI INPUT, and enables the MIDI signal to be passed on to the next device in the chain. This simple arrangement works well, but as always, there can be a few problems. There are two main problem areas:

1: If the chain is extended so that many MIDI devices are connected in this way, signal degradation can occur. This is caused by the MIDI signal being passed through INPUT and THRU' circuitry. The serial MIDI signal suffers from propagation delay, and pulse width distortion. Whilst this does not cause problems with only two or three MIDI devices, the effects are cumulative and if a number of MIDI devices are connected, the MIDI signal may become corrupted. Corruption of data can cause all manner of problems, such as notes becoming 'stuck'.

2: The chain can only work if the MIDI devices are equipped with MIDI THRU'. The final device in the chain does

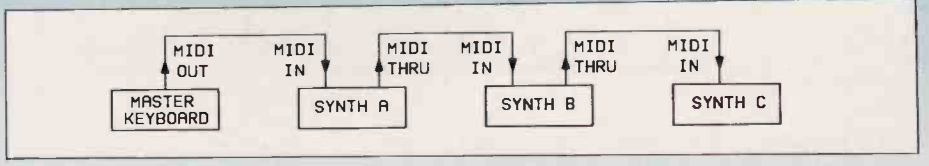


Figure 1. Connecting synthesisers using MIDI chain.

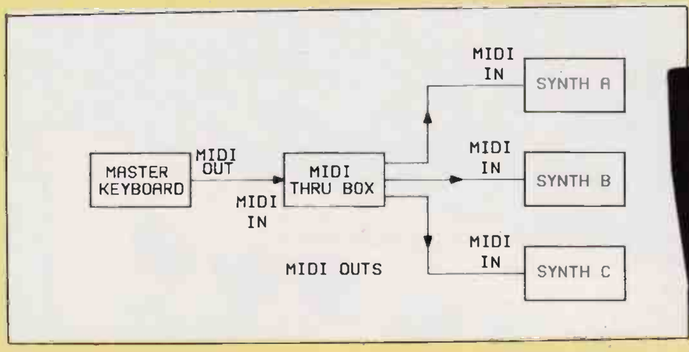
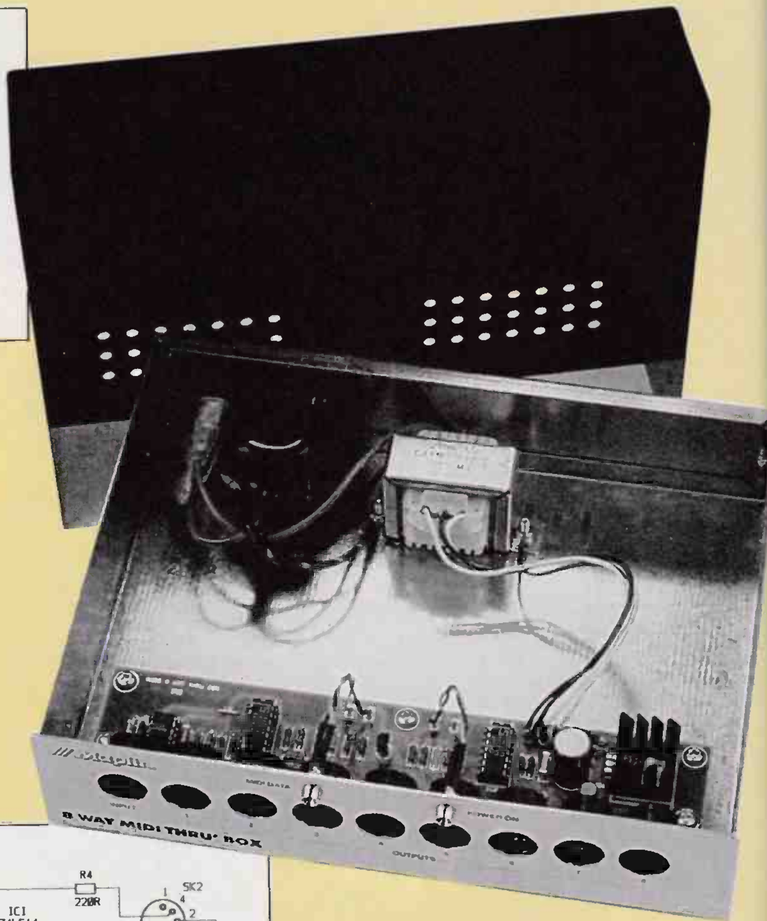


Figure 2. Connecting synthesisers using MIDI Thru' Box.



not have to have MIDI THRU' as it is not relaying the MIDI signal, but if two devices are not equipped with MIDI THRU', then the chain cannot be completed.

To overcome these problems, an 8 way MIDI THRU' box was developed, it is used as shown in Figure 2. The MIDI OUTPUT from the Master Keyboard is connected to the MIDI INPUT of the MIDI Thru' Box, and the MIDI OUTPUTS from the MIDI Thru' Box are connected to the MIDI INPUTS of Synthesisers A, B and C.

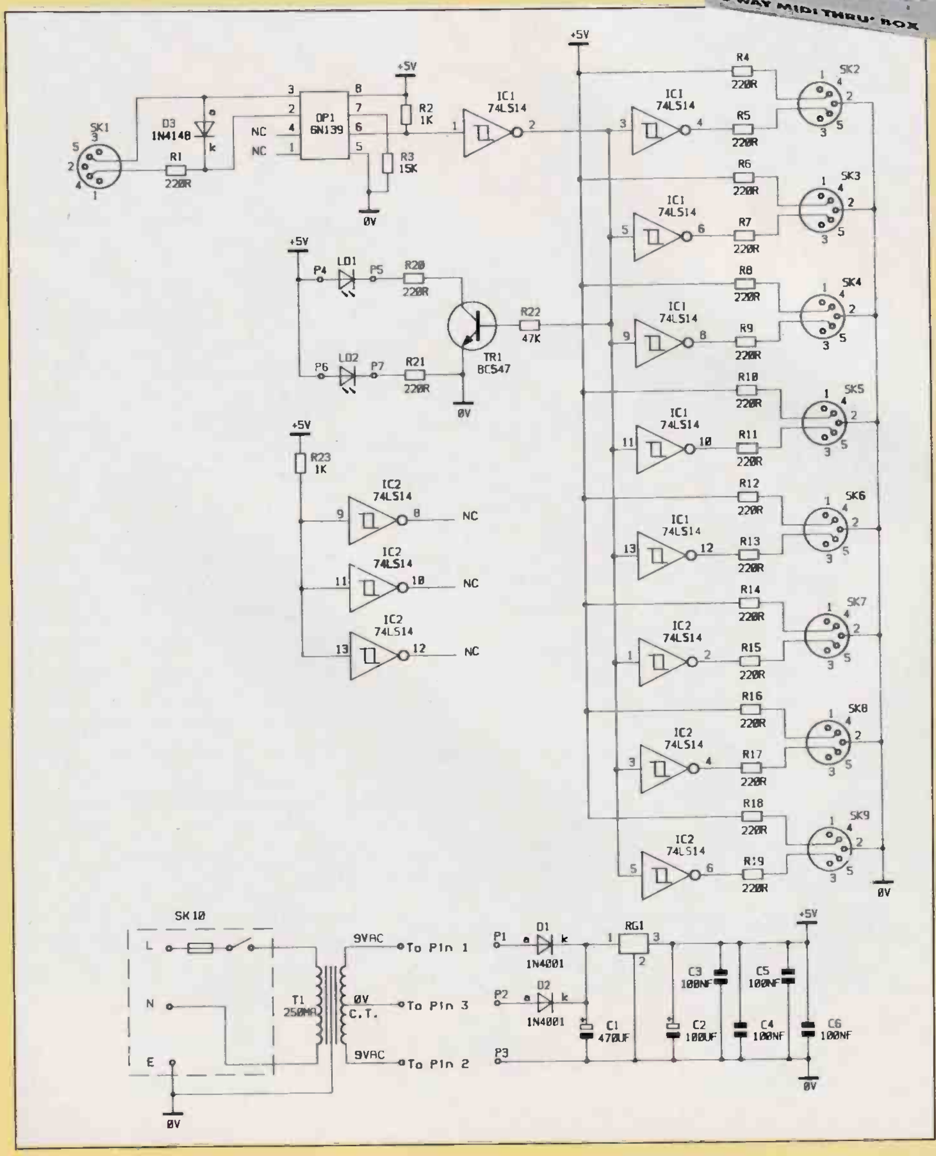


Figure 3. Circuit diagram of MIDI Thru' Box.

Circuit Description

The circuit diagram for the 8 way MIDI Thru' Box is shown in Figure 3. The MIDI INPUT circuitry is formed around SK1, R1, D3 and OP1. OP1, a 6N139, was specifically chosen because of its high sensitivity and capability to handle the high MIDI data rate of 31,250 bits per second. The MIDI signal from SK1 passes through R1, a current limiting resistor to OP1, D3 affords reverse bias protection for the LED in OP1. The serial MIDI signal causes the LED in OPTO1 to turn on and off, the LED emits infra-red light when turned on, which falls on the photo diode, see Figure 4. When the photo diode conducts, the split darlington transistor pair turns on, pulling the output pin 6 low. R3 serves to optimise the transfer characteristic of OP1, the value chosen ensures fast rise/fall time and good sensitivity. R2 is the collector load/pull-up for the open collector output of OP1. The MIDI signal from pin 6 of OP1 is squared up, inverted and buffered by IC1a. The output from IC1a is used to drive eight identical buffer stages. IC1b, R4, R5 and SK2 form MIDI OUTPUT number 1, IC1b re-inverts and buffers the MIDI signal. R4 and R5 limit the maximum current that can be drawn under possible fault conditions, protecting the Thru' Box and the MIDI device driven. LD1, R20, TR1 and R22 form the MIDI data indicator. LD1 will illuminate/flash in response to incoming MIDI data. LD2 is the power on indicator and R21 serves to limit the current through LD2. Unused inputs to inverters IC2d, e and f are pulled high by R23. The Thru' Box is powered by an integral mains power supply. SK10 is an all-in-one mains input socket, fuse holder and on/off switch, this reduces the number of holes required in the rear panel to one (therefore saving elbow grease!). The low voltage supply is provided by T1, a 9V 250mA transformer, the output of which is rectified by a full wave rectifier formed around D1 and D2. C1 is the power supply reservoir capacitor and the +5V regulated supply is provided by RG1. C2, C3, C4, C5 and C6 decouple the supply at various points around the circuit. If required an external AC/DC adaptor (e.g. XX09K) can be used in place of T1. Connect positive to P1 and negative to P3; an input voltage of approximately 9 to 12V DC is suitable.

Construction

Assembly of the project is very straightforward as most of the components are mounted on the PCB. Removal of misplaced components is quite difficult so please double-check each component type, value and its polarity where appropriate, before soldering! The PCB has a printed legend to assist you in locating where each component goes, see Figure 5, and refer to the parts list.

The sequence in which the components are fitted is not critical, but the following order will probably be found to be the easiest. First insert the five pins, designated P1 to P5, into the track side of the board and push them home with a hot soldering iron, then solder them in. Identify and fit the resistors and the capacitors, note C1 and C2 are polarised electrolytics and must be inserted with correct polarity. Using off cuts from the resistors (you didn't throw them away did you?) fit the two wire links designated LK. Next fit the IC sockets ensuring that the orientation indicator lines up with the corresponding mark on the PCB legend, but *do not* insert the ICs or the opto-isolator. Insert the diodes and the transistor, again ensuring correct orientation. Referring to Figure 6, fit the regulator RG1 and heatsink. Last, but not least, fit the PCB mounting DIN sockets, making sure that they butt together neatly. Before proceeding any further, check over the board, paying special attention for splashes of solder across adjacent joints and incorrectly placed components. Check also that the component leads are properly trimmed.

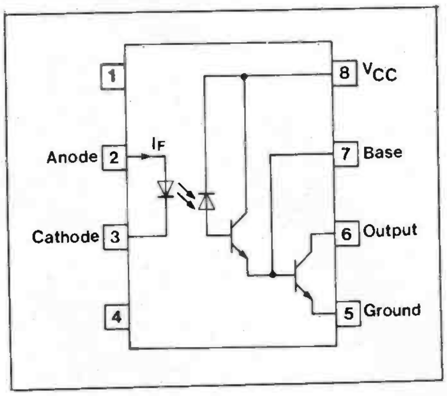


Figure 4. 6N139 opto-isolator.

Box Assembly and Wiring

Box 2105 is recommended for housing the project as it is neat, strong and durable, but it is not included in the kit as you may wish to mount your PCB in a set-up of your own. A printed front panel is also available for this project and this too is not in the kit. Figure 7 shows box drilling details.

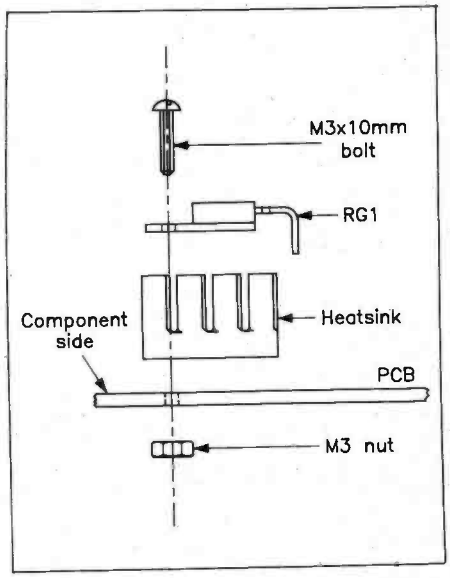


Figure 6. Assembly of regulator and heatsink.

If you do decide to use the recommended box then assembly begins by fitting the combined mains inlet socket, SK10. This should be fitted with the on/off switch toward the edge of the box; the socket clips into place. Next, with T1's mains leads toward the rear of the box, bolt T1 to the bottom panel using the M3 × 10mm bolts, washers and nuts. A solder tag should be placed underneath each of

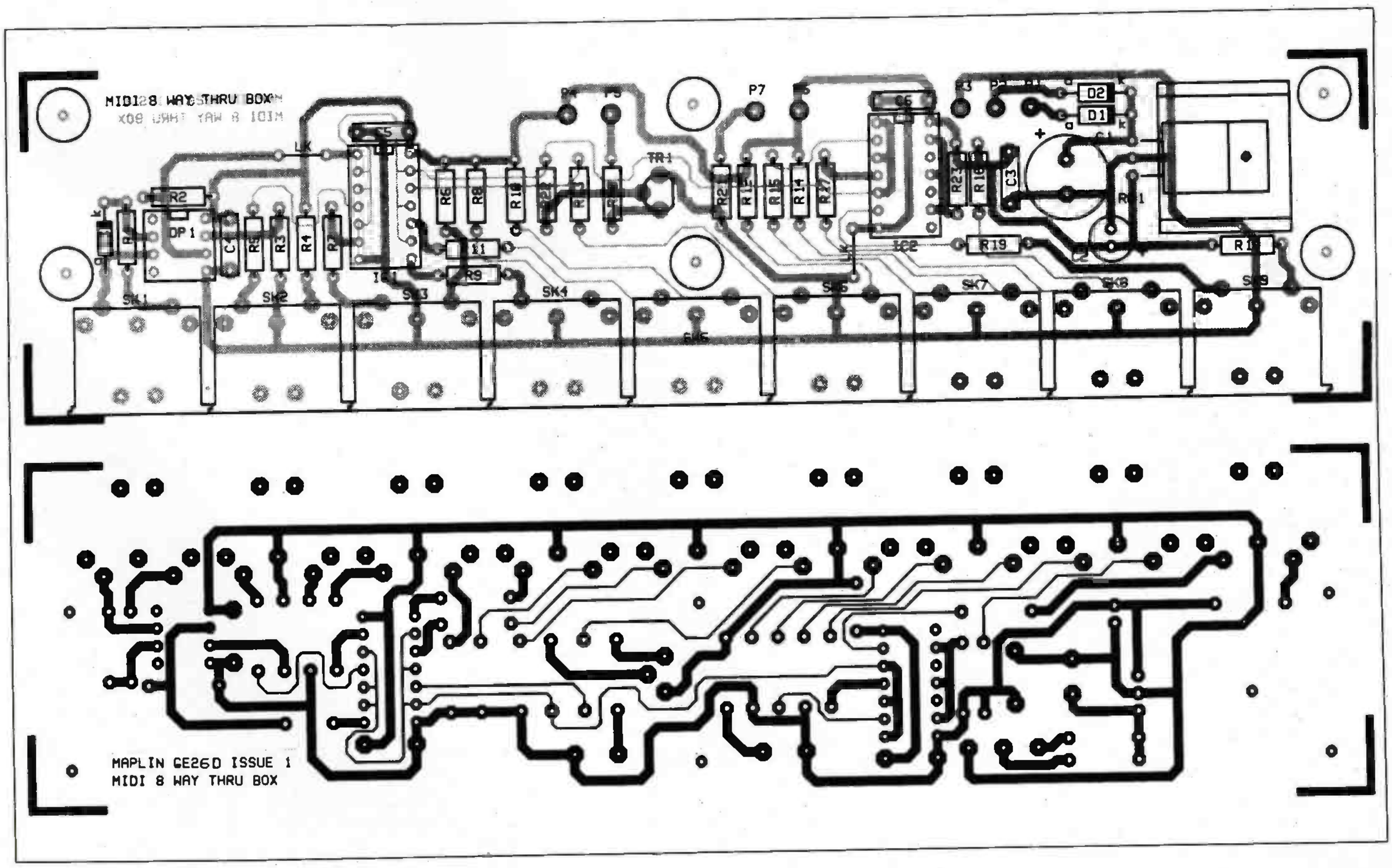


Figure 5. PCB legend and foil pattern.

the nuts, these will be used for earth connections. The ventilation slots are conveniently spaced for the mounting lugs of T1, use the second slot from the end of each group a indicated in Figure 7. Bolt the six M3 threaded spacers to the bottom panel using M3 x 6mm bolts, place the assembled PCB on the spacers, line up the holes and secure the PCB using M3 x 6mm bolts. Bolt on the front panel using countersunk M2.5 x 6mm bolts and M2.5 nuts, stick on the self adhesive printed panel ensuring that the holes are aligned. Fit LD1 and LD2 to the front panel.

Referring to the wiring diagram, Figure 8, complete the wiring for the mains socket, transformer and PCB. Take particular care with the mains connections, it is extremely important that the colour codes for the mains wiring are adhered to. Use covers on the push-on receptacles and cover the terminals on the rear of the mains inlet socket by sliding over the insulating boot. Ensure that the green/yellow earth wire is properly connected to both the earth terminal on the mains inlet socket and the solder tag fitted to T1 mounting bolt. Connect the three secondary wires to the PCB, the 0V (C.T.) wire to P3, one 9V AC wire to P2 and the other 9V AC wire to P1. Using black 16/0.2 wire, connect P3 to the other solder tag fitted to T1 mounting bolt. Finally using red and black 7/0.2 wire, connect LD1 and LD2 to P4, 5, 6 and 7, ensure that the anode/cathode connections are made with the correct polarity. The anode is indicated by either a longer lead or a + symbol on the case adjacent to the lead. It is a good idea to use heat-shrink sleeving on LD1 and LD2 to prevent short circuits.

Testing

Initial testing is made without IC1, IC2 or OP1 fitted. Since mains voltage is connected during initial tests, great care should be exercised so as not to come in contact with live terminals. Remember a mains shock can be lethal! Wire the euroconn lead to a 13A plug fitted with a 2A fuse and connect the MIDI Thru' Box to the mains. Operate the on/off switch on SK10, and LD2 should light. Using a multimeter (analogue or digital) check that +5V is present on pin 14 of IC1 and IC2 and pin 8 of OP1. Switch off and unplug the MIDI Thru' Box. Fit IC1, IC2 and OP1, ensuring correct orientation and screw the top cover onto the box. Connect the MIDI Thru' Box into a MIDI set-up, e.g. as shown in Figure 2. Sending MIDI data from the master MIDI device will cause LD1 to illuminate/flash and the slave devices to operate as directed by the master device.

Using the MIDI Thru' Box

The MIDI Thru' Box can be used in any MIDI set-up where a number of MIDI devices need to be connected, this includes master keyboards, sequencers, synthesisers, expander modules, drum machines and MIDI controlled effects units.

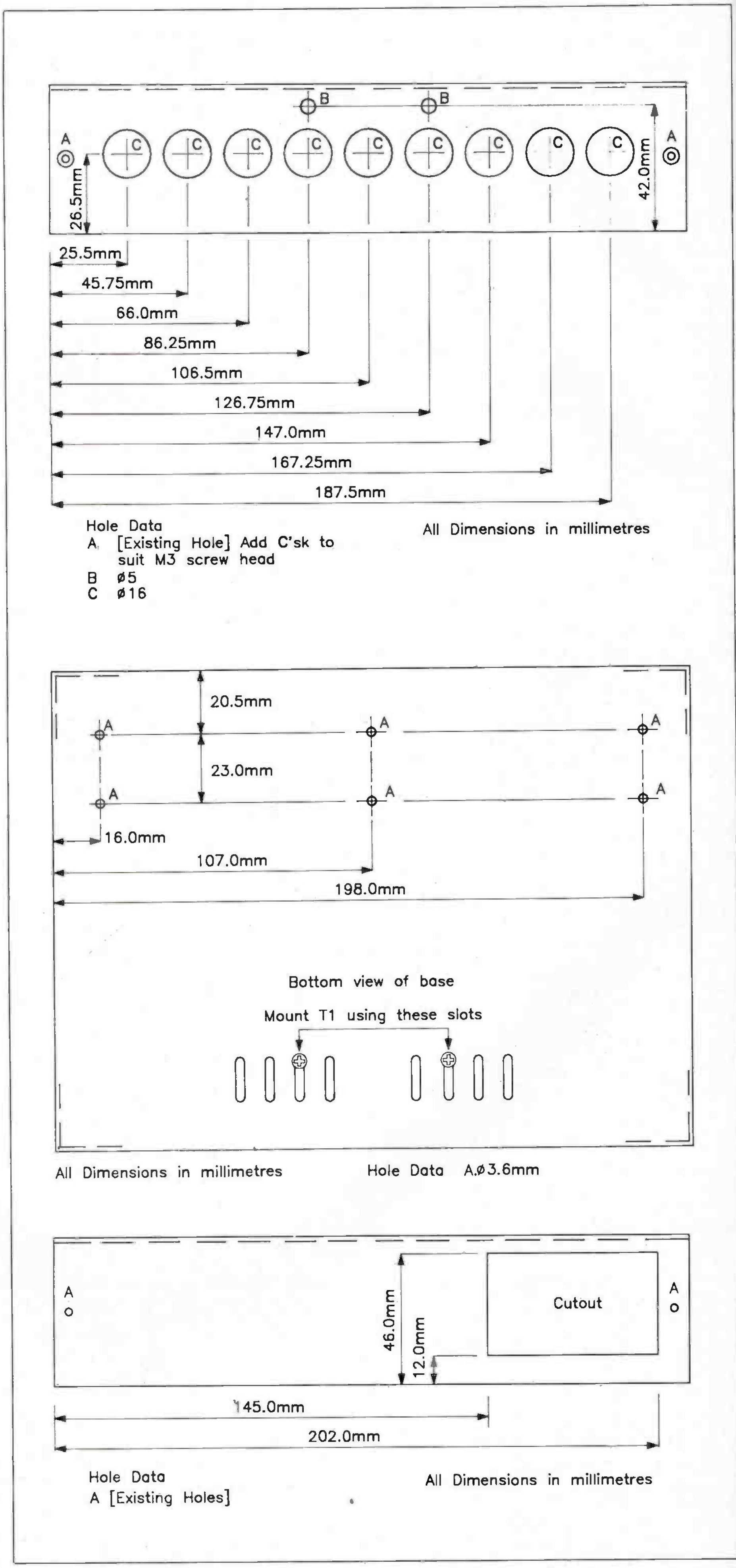


Figure 7. Box drilling details.

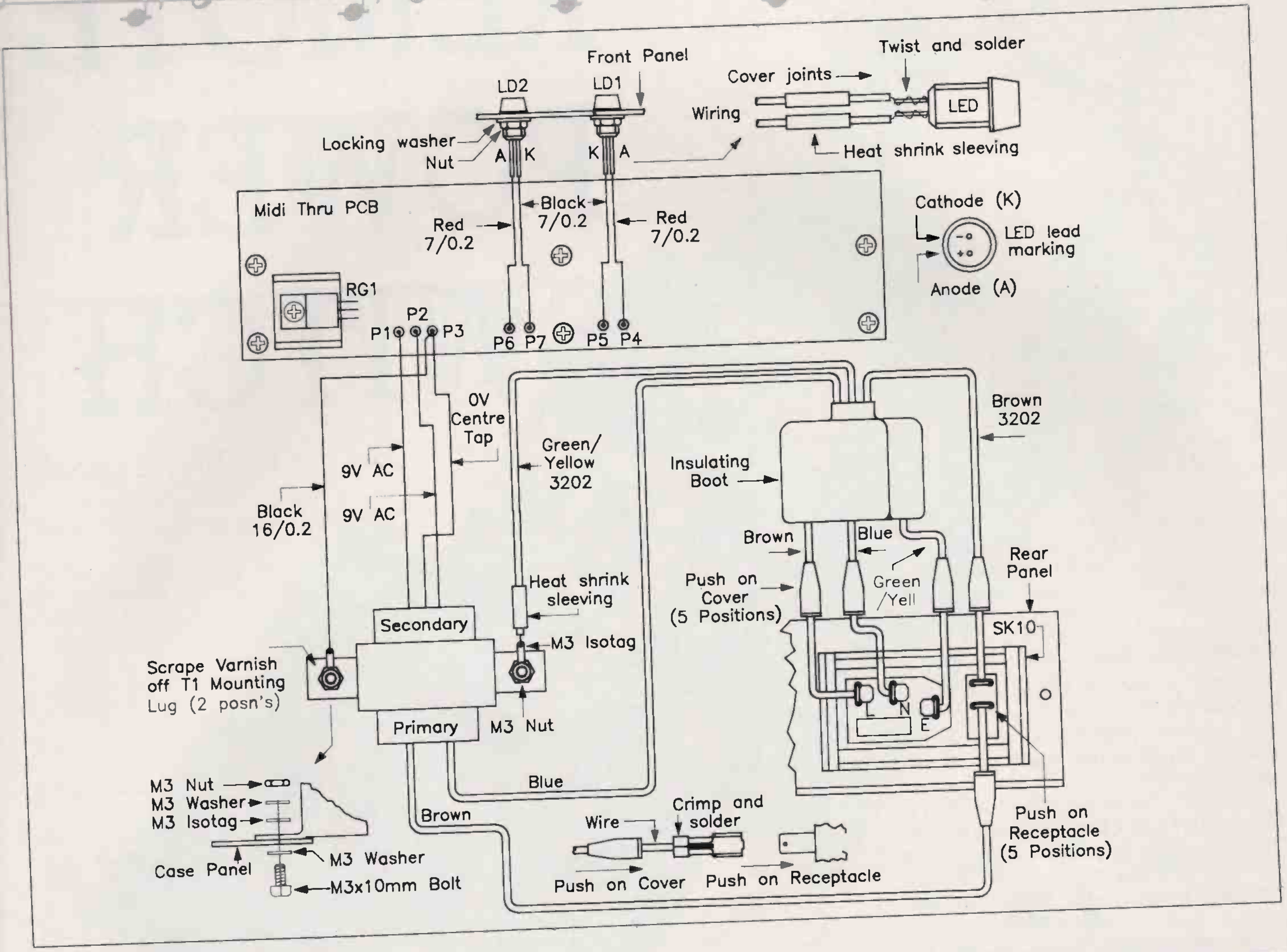


Figure 8. Wiring and assembly diagram.

MIDI THRU' BOX PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,4 – 21	220Ω	19	(M220R)
R2,23	1k	1	(M1K)
R3	15k	1	(M15K)
R22	47k	1	(M47K)

CAPACITORS

C1	470μF 35V PC Electrolytic	1	(FF16S)
C2	100μF 10V Minelect	1	(RK50E)
C3,4,5,6	0.01μF Poly Layer	4	(WW29G)

SEMICONDUCTORS

D1,2	1N4001	2	(QL73Q)
D3	1N4148	1	(QL80B)
LD1,3	Chrome LED Small	2	(YY59P)
TR1	BC547	1	(QQ14Q)
RG1	μA78M05UC	1	(QL28F)
IC1,2	74LS14	2	(YF12N)
OPTO1	6N139	1	(RA59P)

MISCELLANEOUS

T1	250mA Tr 9V	1	(YN15R)
SK1 – 9	PC DIN Skt 5-pin	9	(YX91Y)
SK10	Fuse/Switch Inlet	1	(JK71N)
	Ins Cover	1	(JK67X)
	DIL Skt 8-pin	1	(BL17T)
	DIL Skt 14-pin	2	(BL18U)
	Euroconn Lead	1	(BW99H)
	Printed Circuit Board	1	(GE26D)
	Push-on Receptacle	1 Pkt	(HF10L)
	Push-on Recep Cover	1 Pkt	(FE65V)
	Wire 3202 Grn/Ylw	1 Mtr	(XR38R)
	Wire 3202 Brown	1 Mtr	(XR34M)
	Heat shrink CP16	1 Mtr	(BF68T)
	7/0.2 Wire Red	1 Pkt	(BL07H)
	7/0.2 Wire Black	1 Pkt	(BL00A)
	16/0.2 Wire Black	1 Pkt	(FA26D)
	Pins 2145	1 Pkt	(FL24B)
	Fuse 20mm 100mA	1	(WR00A)
	Vaned Heatsink	1	(FL58N)

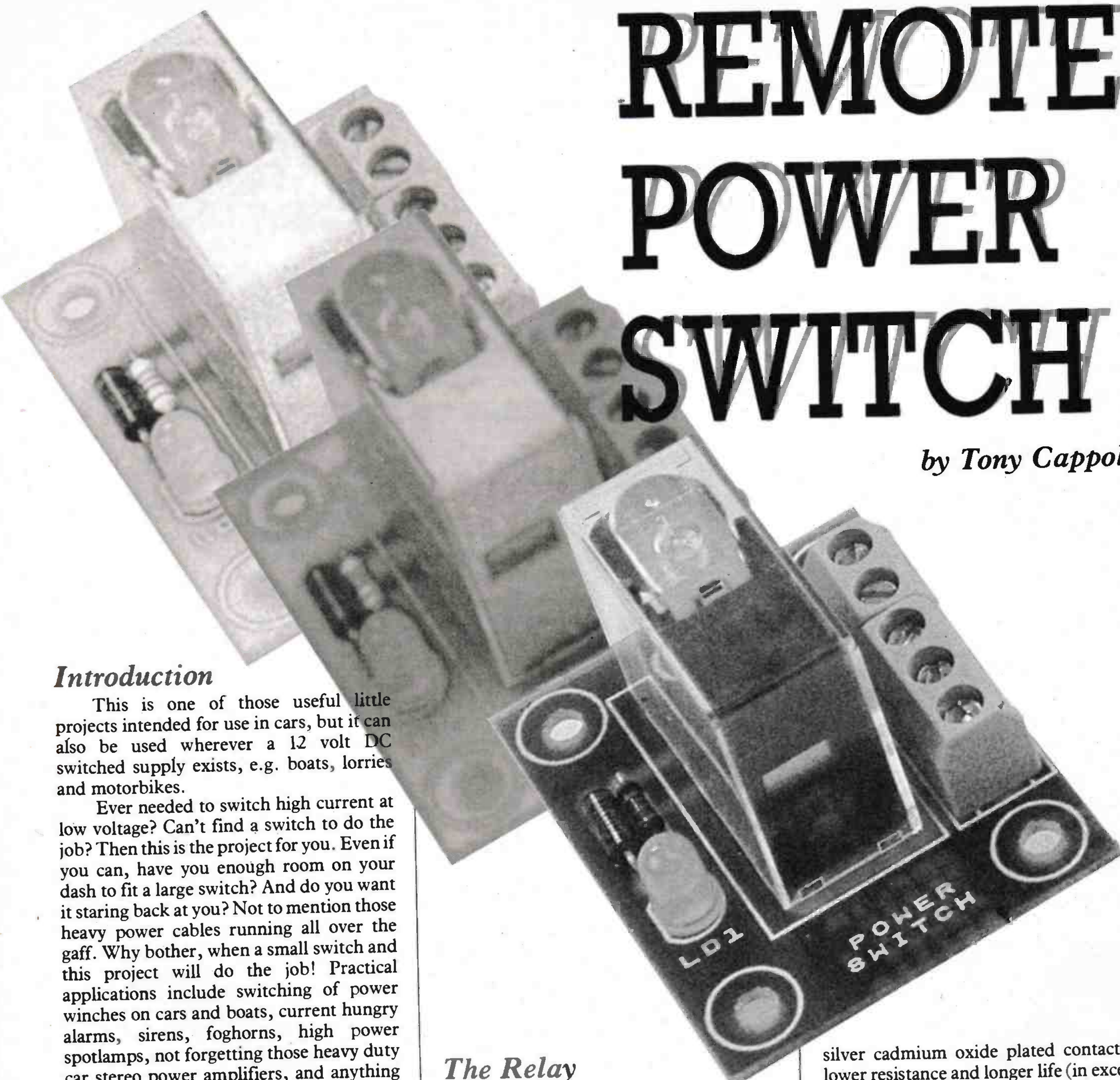
OPTIONAL

Isonut M3	1 Pkt	(BF58N)
Isobolt M3 10mm	1 Pkt	(HY30H)
Isobolt M3 6mm	2 Pkts	(BF51F)
Isotag M3	1 Pkt	(LR64U)
Isowasher M3	1 Pkt	(BF62S)
Threaded Spacer M3	1 Pkt	(FG38R)
Pozi Screw M2.5 6mm	1 Pkt	(BF39N)
Isonut M2.5	1 Pkt	(BF59P)
Box 2105	If req	(XJ29G)
MIDI Thru' Panel	If req	(JP98G)
13Amp Plug Nylon	If req	(RW67X)
Plug Fuse 2A	If req	(HQ31J)

The parts listed above, excluding Optional items, are available as a kit:
Order As LP08J (MIDI Thru' Kit) Price £21.95
The following items are also available separately, but are not shown in our 1989 catalogue:
MIDI Thru' PCB **Order As GE26D Price £3.45**
MIDI Thru' Front Panel **Order As JP98G Price £3.45**

REMOTE POWER SWITCH

by Tony Cappolli



Introduction

This is one of those useful little projects intended for use in cars, but it can also be used wherever a 12 volt DC switched supply exists, e.g. boats, lorries and motorbikes.

Ever needed to switch high current at low voltage? Can't find a switch to do the job? Then this is the project for you. Even if you can, have you enough room on your dash to fit a large switch? And do you want it staring back at you? Not to mention those heavy power cables running all over the gaff. Why bother, when a small switch and this project will do the job! Practical applications include switching of power winches on cars and boats, current hungry alarms, sirens, foghorns, high power spotlamps, not forgetting those heavy duty car stereo power amplifiers, and anything else you can think of.

Simply run a pair of power cables (of adequate size and unconnected) from the vicinity of the supply, and connect to the equipment. Break into the positive supply line at the most convenient point, and insert the power switch board. Next, a pair of light duty wires (zip wire XR39N) can be taken back to the dashboard where a small control switch is fitted. A second pair of wires may be required if the LED is removed from the PCB and fitted to the dash to give visual indication of operation. Figure 1 shows the wiring layout for most applications, and Figure 2 the layout for speaker switching. Remember, this project is not waterproof and will also need fuses, one fuse for the coil (50mA), the other fuse is for the equipment at 16A maximum, and which also stops the relay contacts being welded together in the event of a short circuit! Care must be taken if fixing the circuit board onto metal surfaces to avoid shorting the contacts, a good idea would be to use some M3 x 10mm insulated spacers (FS36P), alternatively a small plastic box with mounting base (YN37S) would prove to be ideal for this application.

The Relay

This relay was chosen for its excellent immunity to vibration, rendering itself ideal for this application. The relay is a single pole double throw (SPDT) type with silver cadmium oxide plated contacts for lower resistance and longer life (in excess of 100,000 switching operations). At 12 volts, the relay can cope with 10 Amps DC, 20 Amps AC for a make contact, and 10 Amps DC, 5 Amps AC for a break contact (all

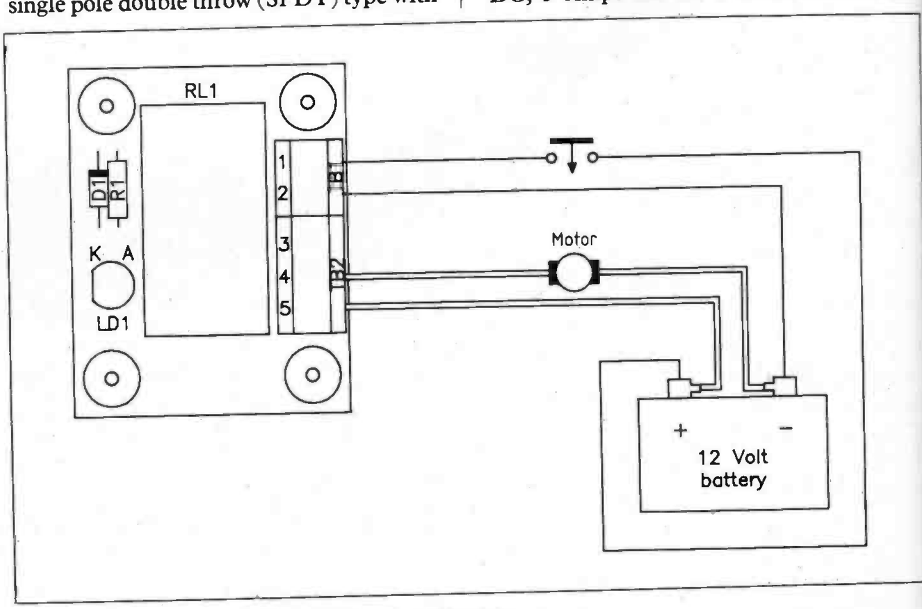


Figure 1. Wiring diagram for motor/most applications.

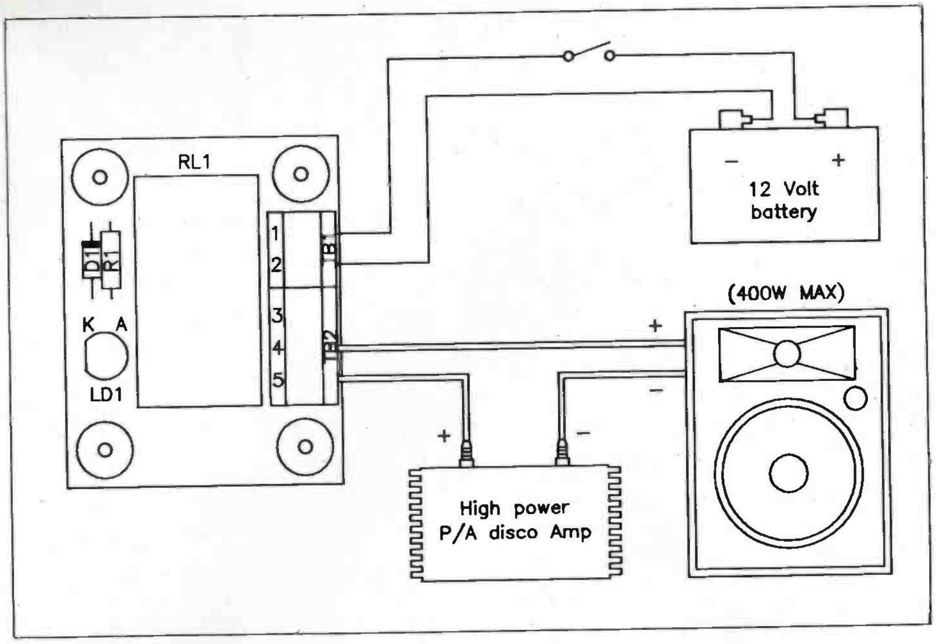


Figure 2. Wiring for high power speakers.

ratings resistive or inductive). The resistance of the coil is 270Ω which means that only 45mA will be consumed from the driver circuit.

Circuit Description

This circuit could not be simpler; see Figure 3. The diode D1 is used to prevent any back emf damaging whichever type of driver circuit used, caused by the collapse of the magnetic field around the coil, i.e. the 'J' terminal becoming more positive than the supply rail. LD1 is included to show it and when the relay is operating, and R1 to limit the current through LD1. Connections to the circuit board are made via screw terminals for easy fitment; terminal block TB1 is for connecting the power to energise the coil terminal 1, and the switched supply, terminal 2, or 0 volt. TB2 provides for connecting to relay contacts 3, 4 and 5, where terminal 3 is the normally closed contact (N/C), terminal 4 is the common connection, and terminal 5 is the normally open contact (N/O).

Construction

Please refer to the construction guide supplied with the kit for soldering and constructional techniques. The PCB supplied is of high quality fibre glass board, with a legend to aid construction – part number GE25C. First mount the resistor (solder and crop the leads as you go), then the diode D1 (making sure the diode is fitted the correct way round) followed by the LED LD1 – the cathode (K) is the short lead or flat side on the package which faces away from the relay. If the leads on any component are tarnished, then clean with a fine grade wet and dry paper to make it easier to solder. Next fit the screw terminals and lastly, mount the relay. Having now fitted all the components, check for solder splashes and bridges and re-check D1 and LD1 against Figure 4. The PCB may now be cleaned of flux residue using suitable solvents (YJ45Y).

Testing

To test this project, apply 9-14 volts DC to terminal 1 and 0 volts to terminal 2. If all is well, the LED will light and the relay will operate, but if power is connected to the board the wrong way round, D1 will be damaged and will have to be replaced.

Relay Specifications

Coil voltage Min/Max at 20°C	8.9-21.3
Coil resistance	270Ω max
Ambient temp °C	−25/+70
Max switched current	16A
Max contact load (resistive)	400 VA
Max number of switching operations	200,000
Max number of switching operations per sec	20
Turn on time	13 ms
Turn off time	4 ms

Terminal Connections

T1=COIL +V
T2=COIL −V
T3=RL1 N/C
T4=RL1 C
T5=RL1 N/0

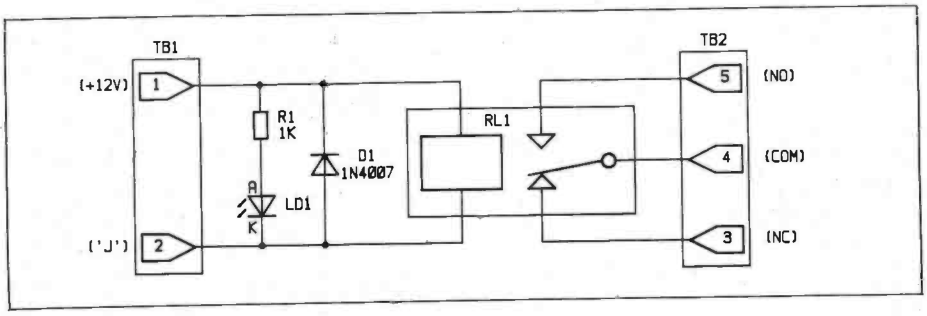


Figure 3. Circuit Diagram.

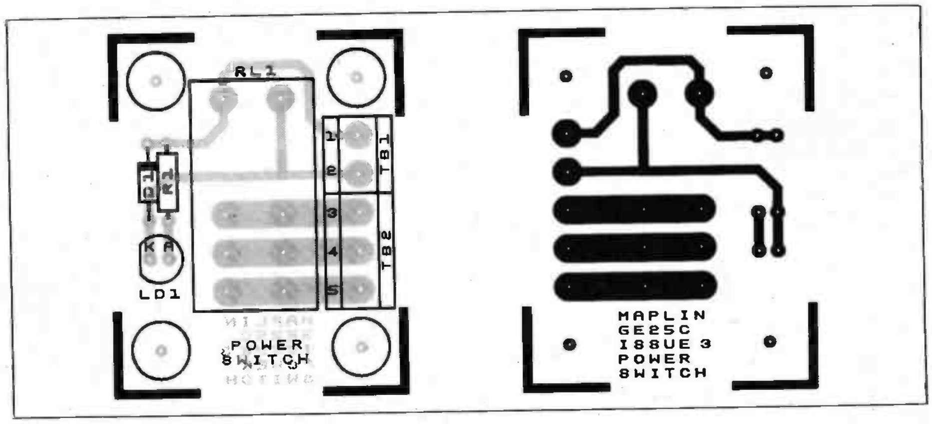


Figure 4. PCB layout.

REMOTE POWER SWITCH PARTS LIST

RESISTORS: All 0.6W 1% Metal Film			
R1	1k	1	(M1K)
SEMICONDUCTORS			
D1	1N4007	1	(QL79L)
LD1	Red LED	1	(WL27E)
MISCELLANEOUS			
TB1	2 Way PC Terminal	1	(FT38R)
TB2	3 Way PC Terminal	1	(RK72P)
RL1	Relay SPDT 12V DC 16A	1	(YX99H)
	Power Switch PCB	1	(GE25C)
	Constructors Guide	1	(XH79L)

The above items are available as a kit:
Order As LP07H (Power Switch Kit) Price £4.95
The following item is also available separately, but is not shown in our 1989 catalogue:
Power Switch PCB **Order As GE25C Price £1.95**

As yet no heads have rolled, barricades built or bustles stormed, but a new French revolution is well under way. Despite having been invented in the UK, the French have taken the undisputed world lead in videotex systems where a computer terminal can access national and international information services. Michael Naughton of communications consultancy Applied Network Research describes the decision by France Telecom to undertake the widespread introduction of their Teletel network service by issuing, free of charge, their Minitel terminals, as being highly imaginative. BT may well complain of having been hijacked, but the industry believes that France Telecom has pulled off one of the major information technology success stories of the 80's.

As Bill Loose of the PA Consultancy confirms, the French Minitel terminal was originally introduced as a method of replacing printed telephone directories for the 25m or so French telephone subscribers. "The Minitel movement is an audacious technological gamble which has turned out to be a runaway success. The Minitel has become part and parcel of everyday life in France".

When France Telecom decided to implement videotex on a scale not even imagined in other countries, the concept was largely untried. But the Electronic Telephone Directory Service was quickly joined by numbers of Teletel services operated by independent information service providers. The resultant fast growth says France Telecom was due in part to the issue of free Minitel units and the rapid extension of the systems geographical coverage.

This, says Bill Loose, is the understatement of the year. "France Telecoms became the undisputed champion of the videotex market-place world-wide solely because the PTT authority provided their Minitel videotex terminals free of charge".

Minitel 1B Keyboard.

NEW FRENCH REVOLUTION GATHERS PACE

by Alan Simpson

Outside of France, the videotex movement remains very much a chicken and egg situation, says ANR's Michael Naughton. "The service information providers are hesitating until there are enough users to assure profits. Meanwhile potential customers hesitate to invest in a terminal until a large number of services are available".

Rumours Galore

The comms industry, states PA's Bill Loose, was awash with rumours earlier this year that British Telecom was about to introduce a cheap videotex service for its 23m telephone customers. "But the industry, while welcoming the movement, especially the potential terminal manufacturers, feared

Minitel with Printer.

that BT, rather than follow the French Minitel technology movement, would go their own way. In any case the much publicised BT Chatline problems probably set the universal terminal cause back a few notches or so.

But before we get too immersed into the technologies and techniques of videotex, a few explanatory notes might be useful. To be somewhat formal, videotex is the generic name for services or systems which link interactive user terminals to a host computer through the Public Switched Telephone Network. Fortunately Michael Naughton is on hand to define a less high-tech description. Videotex, he says, involves large scale information databases that can be easily accessed. They relate to an interactive 2-way system which displays computer network derived information. Users can review and book their travel arrangements for example or check on airline flights.

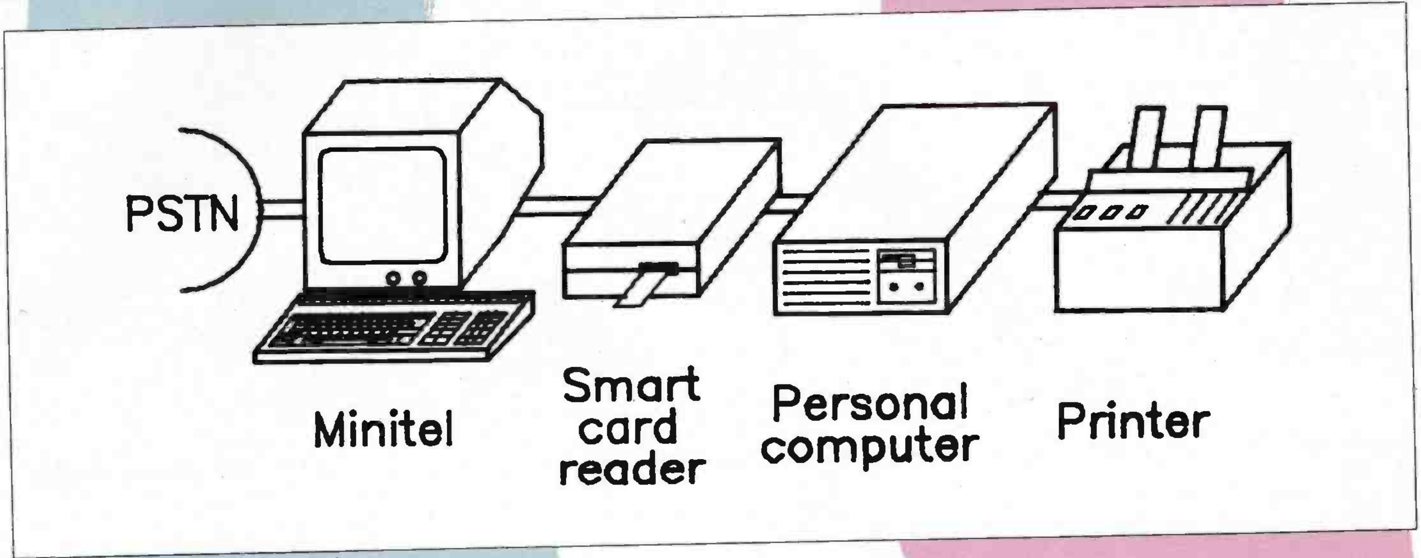
to replace – probably free of charge – some 9m obsolete telephones throughout the country.

Meanwhile, pressure, or perhaps more accurately complaints, are raining down on BT's operator directory service. As a result, the temptation to do away with the manual directory response system which apparently costs BT some £80m a year, and follow the French PTTs lead in supplying an on-line electronic directory, must be hard to resist. If only to get some revenues from the extensive use of the directory service by phone-based marketing teams.

But at least one industry observer, Dr. Annette Nabani of the PA Consultancy, does not see BT launching a large scale Minitel terminal give-away operation. "It is more likely that BT will issue a Minitel-type card which will allow subscribers to connect their computers to the public telephone network".

was the inspired introduction of the Electronic Telephone Directory service, where subscribers were offered a free, though basic, Minitel terminal to access the system network. This national network, Transpac, is a public switched data network for information transport, an intelligent network which can handle well over 50,000 simultaneous calls in France.

In the Teletel system, the usually dumb user terminals are attached to the Public Switched Telephone Network (PSTN) while most host computers are attached to the Transpac network. Interworking between the two networks is by special switching nodes. With, already, close to five million Minitel units in use – though how many of this number are lodged in cupboards and attics are not known – and the number increasing by 80,000 per month (largely in line with the roll-up programme which withdraws phone



Minitel with daisy-wheeled peripherals.

Teletel is the French videotex system which can be accessed by the 'cheap' Minitel terminal. Just to confuse the matter, Teletel makes extensive use of the French national carrier network Transpac.

In terms of French revolutions, videotex has a fairly short, but fairly dramatic life. This year sees the 10th anniversary of the BT's videotex service Prestel. In that time it has only managed to generate some 100,000 terminals, compared to the four million plus Minitels in France.

Somewhat misguidedly, BT – or the Post Office as it was then – saw Prestel as being primarily a domestic service, linking the tv set with the phone with the help of a small keyboard. The spread of the home computer, PCs and intelligent terminals, together with the growth of networks and value added data services, has made redundant the tv connection.

A further hesitation factor is the high BT telephone charges which even before the recent increases were nearly 25% higher than those operated by France Telecoms. Even so, the pressure on BT to introduce a low cost videotex service is increasing. For BT it could well be a case of now or never if they are to take up the Minitel challenge.

British Telecom, as 'Electronics' was the first publication to reveal, is currently changing the prefix of all its 8m London telephone subscribers and at the same time, having to incorporate postal codes into all directories. And sometime soon, BT is having

BT however, says Ambit Research, are currently talking to a number of computer manufacturers – names include Philips, Amstrad, Sinclair and Acorn – in respect of the production of low cost viewdata terminals for distribution to subscribers. The major stumbling block here seems to be, not surprisingly, the cost of the terminals.

Even so, BT remain firm in their belief that their operating licence would in any case preclude the corporation from issuing free terminals. No one area of BT's operations can be cross subsidised by any other. In particular, the comms regulatory body OFTEL, can be expected to insist that any new service should become profitable within a reasonable period of time. Without doubt, the six years or so it took France Telecom to recoup the cost of issuing free terminals in terms of tariff usage, would be unacceptable to the UK authorities. As a result, BT could be planning to buy in terminals in bulk and offer them at a low cost rent or purchase to subscribers.

For BT of course, the issuing of videotex terminals will stimulate its phone network traffic and therefore improve revenues. But BT, as Ambit Research point out, will also have to simulate the number of information service providers if the system is to be a repeat Teletel success story.

France Telecom opened their Teletel service in Paris six years ago, with full country-wide coverage coming online in 1988. The major boost or incentive to Teletel

directories by district) within a few years, the French terminal population could exceed ten million units. This will easily maintain the French lead of having over 90% of the world's videotex terminal total.

Similarly impressive are the Minitel usage figures. The number of calls now exceeds 65m a month (of these 35m are related to Minitel directory calls) and over 6m hours a month are logged onto the system. France Telecom are forecasting that the terminal traffic will double every two years.

Les Liaisons Dangereuses

Certainly no service generation problem affects the French service. At the last count, and it seems to be somewhat difficult to keep count, there were over 4,000 private and public information database services available to Minitel users. These range from news, weather and sports reports, classified advertising, horoscopes, online travel reservations, and a supermarket price comparison service.

Other services include a nation-wide property advertising service, guidelines on how to complete your income tax form and video games where the contestants could be pitted against another subscriber or a computer. It is even possible to hook up to a mass of time-share software programs plus a national joke service.

What France Telecom describe as their

electronic singles bar variety services is far from being a joke, at least as far as revenues are concerned. The Teletel services which include wife swapping and gay meeting clubs, account for 30% of all tariff revenues. However, in order to curb – or perhaps increase tax revenue flows, an increased VAT rate from 18.6% to 33% has now been imposed on the online dating service.

No such tax considerations would be tolerated by Teletel users for the Intergateau service where a selection of patisseries can be selected, paid by credit card and delivered by the local supplier. Equally popular are the oyster and vino delivery services. Such home shopping services now represent 11% of Minitel revenues and is one of the fastest growing service areas.

Meanwhile, with 30% of Minitels in business offices, the terminal serves to link the company with information database services or operate as an in-house facility for management information, electronic messaging and inventory control.

Costing Matters

Unlike the more traditional videotex charging routines which normally involve a subscription for the desired service, the issue of a related password and the separate issuing of bills, the French Teletel system has no subscriptions, no password and no direct billing. Users costs which are based on the time users are on the system, irrespective of distance, are itemised on their telephone bills.

More recently a 'Kiosk' charging system has been introduced for business users who need to access specialist service providers. This premium rate for Value Added Services however remains low in terms of the cost of making international calls. Although business users pay about £10 a month rental for their Minitel terminals, domestic users receive their units on a free loan basis. For all users, the first three minutes of any directory enquiry call is free.

France Telecom insists that although the Minitel service is still in the red, the user benefits are substantial. A large number of users, thanks to their Minitel terminals, have become computer literate. The system itself certainly comes into the user friendly category, making use of Expert Systems or Artificial Intelligence techniques. In order, for example, to access Le Monde newspaper, users needs only key in Le Monde, not a series of codes or control numbers.

Further developments include the new Minitel terminal 12, which supports smart card readers, banking and bill payments, point of sale and electronic mail services as well as toll free dialling facilities.

Minitel Goes International

As international commentator Michael Naughton of ANR confirms, France Telecom is now taking the international route. In partnership with the leading US network service operator Infonet, Minitel are actively marketing their system to the Bell Operating companies and major information suppliers. A Minitel service which interfaces with the French videotex network, is already up and running in Houston, Texas, and a New York operation is not far off. Special Minitel terminals costing about $500 are being made available together with bridging software for IBM and Apple computing systems.

But all is not easy marketing for Minitel. Progress for example in the Bell South region is not helped by the reputation of the sexually oriented service in France. However, Minitel sales teams have not met such reluctance in such countries as Belgium, Finland, Germany, Holland, Italy, Japan and Spain.

Here in the UK, connection to the Teletel service is only possible through the international telephone network. Tariffs are high and you will need either a Minitel unit or PC gateway cards and software. Direct discussions between France Telecom and British Telecom are not exactly in the high key mode. In much of Europe British Telecom is regarded as being something of a maverick PTT authority – one more concerned with achieving profits than implementing user services.

As PA state, don't hold your breath waiting for BT to introduce a Minitel type service. Minitel is a typical example of a British development being allowed to fall into better hands.

TDA2822M Stereo Amplifier continued from page 7.

DC voltage	Speaker impedance/power (RMS)
3V to 6V	4Ω 1W
7V to 9V	8Ω 1W
10V to 15V	16Ω 1W

Table 3. Selecting a speaker.

in the positive power line to the PCB (P5). When the supply is switched on a current reading of approximately 8mA should be seen. When an audio signal is applied to the inputs this current will increase as the volume control is advanced and at loud settings the current may exceed 260mA.

This completes the testing of the TDA2822M stereo amplifier, now disconnect the multimeter from the unit.

Using the Amplifier

The unit can be used over a wide range of supply voltages and loudspeaker impedances. Table 3 should assist you in choosing the speaker for a given DC supply.

When using the amplifier with headphones, the 32Ω 'Walkman' type are recommended as most come with a stereo 3.5mm jack plug already fitted.

TDA2822M STEREO POWER AMP PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2	4R7	2	(M4R7)
R3	1R	1	(M1R)
RV1	47k Dual Pot Log	1	(FX11M)

CAPACITORS

C1	1000µF 16V PC Electrolytic	1	(FF17T)
C2	100nF Minidisc	1	(YR75S)
C3,4	100µF 16V Minelect	2	(RA55K)
C5,6	470µF 16V PC Electrolytic	2	(FF15R)
C7,8	100nF Polylayer	2	(WW41U)

SEMICONDUCTORS

IC1	TDA2822M	1	(UJ38R)

MISCELLANEOUS

JK1	3.5mm PCB Jack Socket	1	(FK20W)
	Constructors Guide	1	(XH79L)
	PC Board	1	(GE21X)
	Pins 2145	1 Pkt	(FL24B)
	DIL Socket 8 Pin	1	(BL17T)
	Knob KB4	1	(RW87U)

A complete kit of all parts is available:
Order As LP03C (TDA2822M Stereo Amp Kit) Price £5.95

The PCB is available separately but is not shown in our 1989 catalogue:
TDA2822M PCB **Order As GE21X Price £1.95**

ELECTRONICS BY EXPERIMENT

Part 10 by Graham Dixey C. Eng., M.I.E.E.

Introduction

The previous article in this series dealt with various ways in which the SCR could be used. This latter device is just one member of a large family but is probably the most used member. Other devices within this family will be introduced in this article, as will be the use of thyristors with alternating supplies. It is also possible to use SCRs with a.c., and there are a variety of circuits so using them, so many in fact that to cover them all would take a whole book! Both the triac and the quadrac were specifically intended for use with a.c. supplies so, naturally, circuits using them will be included.

This article can be considered to have two distinct sections. The first will introduce more members of the thyristor family, with just enough detail to appreciate what they do and, hence, what they are best used for. The second will discuss a range of circuits which use some of these devices and provide the home experimenter with scope for trying them out so as to learn more about them and, in some cases, provide a useful piece of hardware at the end of it. Hopefully the second section will be the longer one of the two!

The Triac

The characteristics for a triac, together with its circuit symbol, are shown in Figure 1. The obvious difference between this device and the SCR is that it has two 'back to back' diode symbols – implying the ability to conduct in either direction – but still only one gate. The characteristics show that the device is indeed bi-directional. It can be triggered into conduction in just the same way as the SCR, by supplying enough gate current, provided that if has sufficient voltage across it, between its main terminals. Because it is bi-directional, the polarity of this voltage isn't important. Thus, if the supply is alternating, it can be triggered into conduction on either half cycle of the supply. Figure 2 shows what will happen if the gate receives a pulse of current once every half-cycle – the triac is forced to conduct whenever this happens and an alternating voltage is applied to the load.

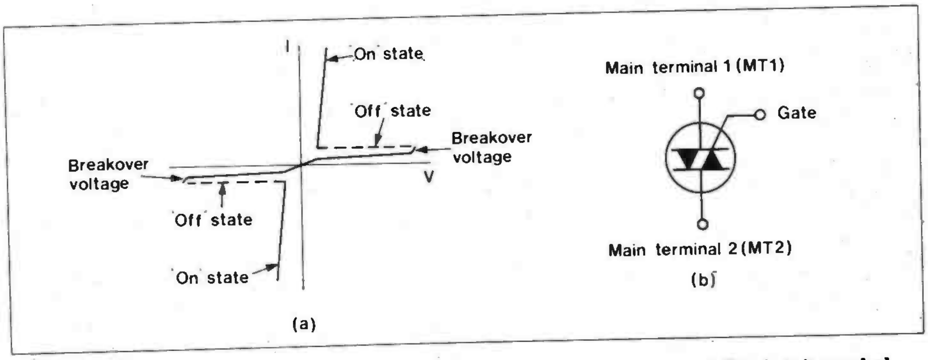


Figure 1. The triac, (a) characteristics, showing bi-directional nature and (b) circuit symbol.

Not only does it not matter what the polarity of the voltage across the triac is, the polarity of the gate current is also not important. Either a positive or a negative pulse will turn the device on. However, if the polarities of the main and gate currents are opposite, the sensitivity is only about half that for the case when they are of the same polarity.

There is an interesting point to be noted about a.c. operation, which applies both to triacs and to SCRs. Referring back to the previous article, one of the difficulties with using SCRs on d.c. supplies was the fact that they had to be 'commutated' in some way by forcing the anode current below a value known as the 'holding current'. When an a.c. supply is used, no special means needs to be employed as, at the end of every half-cycle, the supply voltage falls to zero as a matter of course and the load current is at this instant also zero. Hence, the triac then automatically 'unlatches' and waits in the non-conducting state for the next trigger pulse to arrive at the gate. This assumes that the load is resistive; the situation is slightly different for inductive loads, because zero load voltage and zero load current do not then coincide. For now we will assume resistive loads.

Figure 2 shows that the voltage across

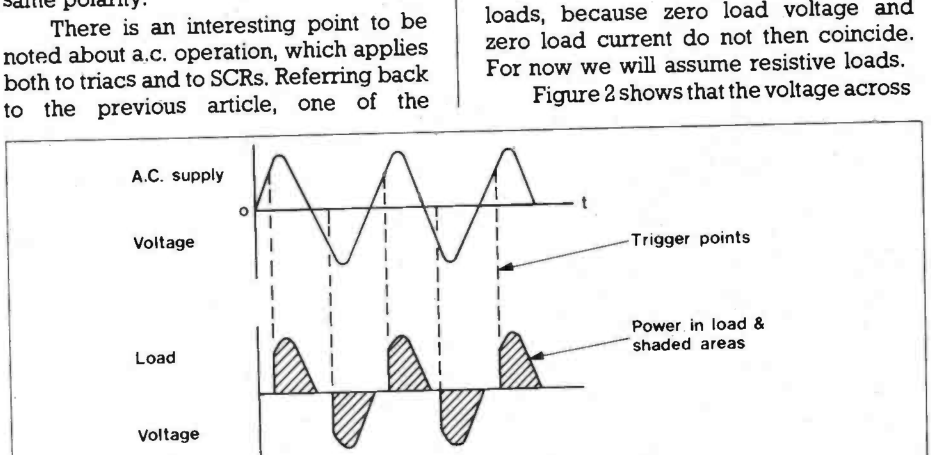


Figure 2. Power control using alternating current. Triggering is regular at the same point in each half-circle, giving a power to the load that is proportional to the shaded areas.

the load consists of a series of half-cycles that are rather less than half sinewaves because the triggering occurs after the beginning of each cycle. This gives a clue to the way in which control of load power can be achieved – by varying the point in time at which the triac is triggered. The later it is triggered, the smaller the area of the half-cycle of load voltage and the smaller the amount of power supplied.

The Diac

The symbol for this device, together with its characteristic, is shown in Figure 3. It is apparent that it is a bi-directional device, like the triac, but without any gate. In fact, it simply switches from the non-conducting state to the conducting one when the voltage between its two terminals exceeds some specific value. The value of this triggering voltage is quite precisely defined for a given diac. This ability to act as a 'voltage sensitive switch' is usefully employed in triggering triacs. The diac is a very low power device whereas triacs are available for a very wide power range. Hence the diac-triac combination consists effectively of a low power thyristor triggering a much higher power thyristor.

The Silicon Controlled Switch (SCS)

The symbol for this thyristor device is seen in Figure 4(a). In this case, we have a device that is obviously only unidirectional but has two gates, known as the 'anode gate' and the 'cathode gate'. Thus, it acts somewhat like an SCR but with the following differences:
(i) It can be turned on by applying either a positive pulse to the cathode gate or a negative pulse to the anode gate.
(ii) Once triggered on, it can be turned off again by applying a negative pulse to the cathode gate or a positive pulse to the anode gate. In this respect it is significantly different from the SCR.

The Silicon Unilateral Switch (SUS)

This device, whose symbol is shown in Figure 4(b), is basically an SCR with an anode gate instead of a cathode gate, and with a zener diode between gate and cathode. The usual mode of operation is with the gate left open, in which case the device acts as a 'voltage-sensitive switch' which turns on when the forward voltage exceeds a given value (usually about 8V). This occurs because of the internal zener breakdown triggering off a regenerative switching action.

The Silicon Bilateral Switch (SBS)

The symbol for this is shown in Figure 4(c). It is nothing more than two SUSs, wired in inverse parallel, and housed in the same package. This allows it to trigger on either polarity of voltage, unlike the SUS itself which can only trigger when the anode is positive with respect to the cathode.

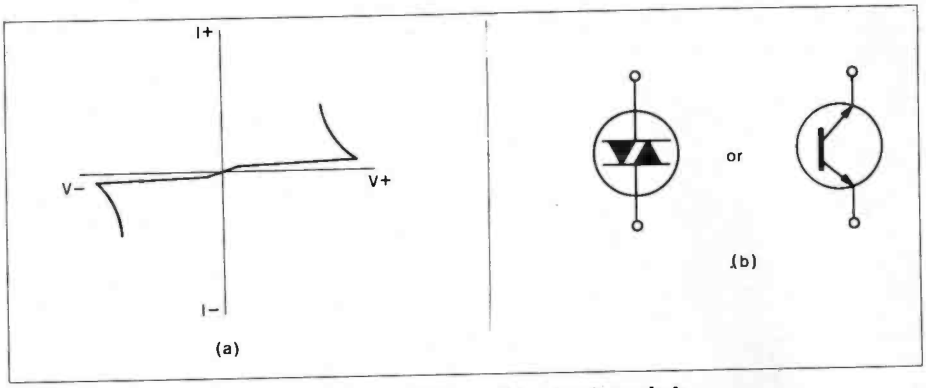


Figure 3. The diac, (a) characteristics, and (b) possible circuit symbols.

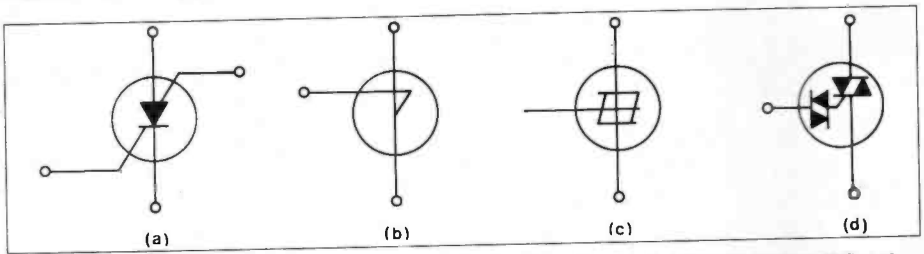


Figure 4. Circuit symbols for four members of the thyristor family. (a) SCS (b) SUS (c) SBS and (d) quadrac.

The Quadrac

Because diacs are so often used to trigger triacs in phase control circuits, the quadrac has been developed in which the diac is a part of the triac's gate structure. Essentially then, this device is a diac and a triac in one package. The symbol is shown in Figure 4(d).

Light Activated Devices

Triggering of some thyristors by means of light is made possible by a type of encapsulation in which one or more junctions are exposed to light. Examples of such devices are the LASCR (Light Activated SCR) and LASCS (Light Activated SCS).

The Programmable Unijunction Transistor (PUT)

This apparently curiously named device, of which the BRY39 is an example, can actually be used in one of three modes.
(i) As a PUT, ignoring the cathode gate, it is useful in a variety of roles which include motor controls, oscillators, timers, triggering and switching, etc.
(ii) As an SCS, using all four connections, in the manner described above under the heading Silicon Controlled Switch.
(iii) As a 'thyristor tetrode', that is a four electrode device in which either gate can be used to control its conduction.

This completes the survey of the major thyristor devices. The UJT or unijunction transistor, often used as a trigger in thyristor circuits, has been seen previously in Parts Eight and Nine of this series.

Experiments with Thyristors

To demonstrate anything really useful with power control devices means using an adequate source of power. With a.c. power control this really means using the mains supply. While this is at least conveniently to hand, it does mean that care should be taken to avoid accidents. Power should only be applied to observe results and should be disconnected while making any changes to the circuit. The lowest possible current fuse should be used in the mains connector, compatible with the load being used – but certainly not greater than 5A. Wiring should be kept neat and of adequate gauge. To avoid burn-out of devices, they should be mounted on an adequate heat sink. Where a resistive load is required an ordinary domestic bulb, 60W or 100W for example, usually provides an effective and convenient choice. If a CRO is used to look at waveforms, it is better if it is not earthed. The 'earthy' side of the CRO can be connected to the neutral line on the test circuit and the CRO input connected to the test point, preferably using an insulated probe or clip of some sort.

Phase Control of Triac Circuits

It is possible to trigger a triac into conduction merely by providing a conductive path to the mains supply through a switch and a current limiting resistor. Such a simple circuit would merely provide on/off control of fixed power and its only advantge over switching the load current directly would be that the switch itself would only have to carry the gate current and not the full load current. However, it is much more useful, and interesting, to be able to control the load power over a reasonable range. One way of doing this is by means of 'phase control'.

A simple phase control circuit is shown in Figure 5, which uses a single time constant, that is a phase-shift network, consisting of RV1 and C1. In

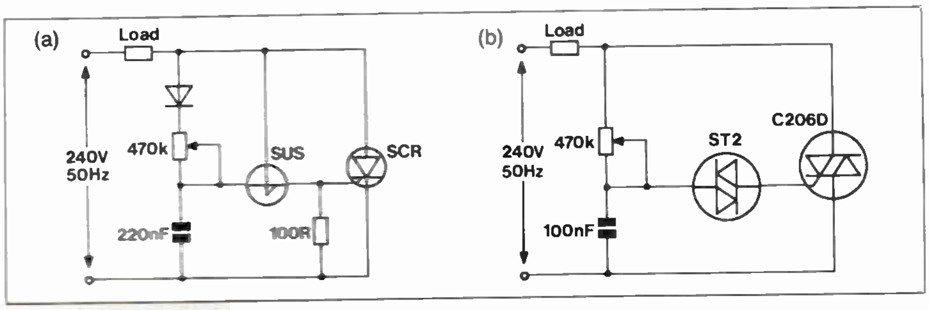


Figure 5. (a) Half-wave phase-control circuit using SUS to trigger a SCR, (b) full-wave phase-control circuit using diac to trigger a triac. Both circuits use single time constants.

Figure 5(a) the trigger device is a SUS, whereas in Figure 5(b) the trigger device is a diac, in this case the ST2 which has a threshold voltage of 32V approximately. When power is applied to the circuit the voltage on the MT2 terminal of the triac, and the voltage across RV1 and C1, both rise sinusoidally. Because RV1 and C1 form a phase-shift network, the voltage at the gate will lag behind the MT2 voltage by 90°. This will be true whatever the value of RV1. The significance of the value of RV1 is that, if it is low, the voltage across C1 (the gate voltage) will reach the SUS or diac triggering voltage quite quickly, whereas if it is high, it will take a lot longer to reach this value. It should be obvious from this that the point in time at which the triac can be triggered can be controlled by variation of RV1. When RV1 is a minimum the triggering point of the trigger device will be reached quite quickly (i.e. early in the cycle); when RV1 is a maximum the triggering point will be considerably delayed and can occur quite late in the cycle.

The circuits of Figure 5 suffer from an effect called 'backlash', the turn on-point in the cycle not coinciding with the turn-off point. It is possible to reduce this effect, in the case of the diac circuit, by placing some resistance in series with the diac, but a better method is to use the 'double time-constant' circuit of Figure 6. This latter arrangement reduces the hysteresis considerably and allows a much wider control of power. Although these circuits are extremely simple they are, nonetheless, quite capable of being used for control of lights, motors and heaters, giving quite good proportional control of these quantities – subject to one or more practical considerations.

Radio Frequency Interference (RFI)

Whenever a switch is closed in order to supply current to a load, whether that switch is mechanical or electronic, a certain amount of radio frequency energy is generated. Some of this is 'air borne' and is not usually strong enough to have any significant effect. Some of it is, however, 'mains borne' and may cause interference with AM radios and TVs. It is relatively simple to reduce mains borne RFI by fitting an LC filter across the mains supply input to the circuit, as shown in Figure 6 by the components L1 and C1. The values quoted should provide effective filtering but it should be remembered that the choke must be wound of an adequate gauge of wire sufficient to carry the full load current; a normal small r.f. choke is not suitable. The filter capacitor should have a working voltage of at least 400V, a polyester type being satisfactory.

Accidental dv/dt Triggering

When the load being switched is inductive – relay coils, motors, etc, there is a phase angle between the load voltage and load current. Consequently, at the moment that the load current falls to zero and the triac turns off, the supply voltage may have quite a high value. This voltage being suddenly applied to the triac may well cause it to switch back on again. The net effect is that the triac is permanently latched on. This can be overcome by an RC 'snubber' circuit, as shown in Figure 7, wired across the triac. Suitable values are given.

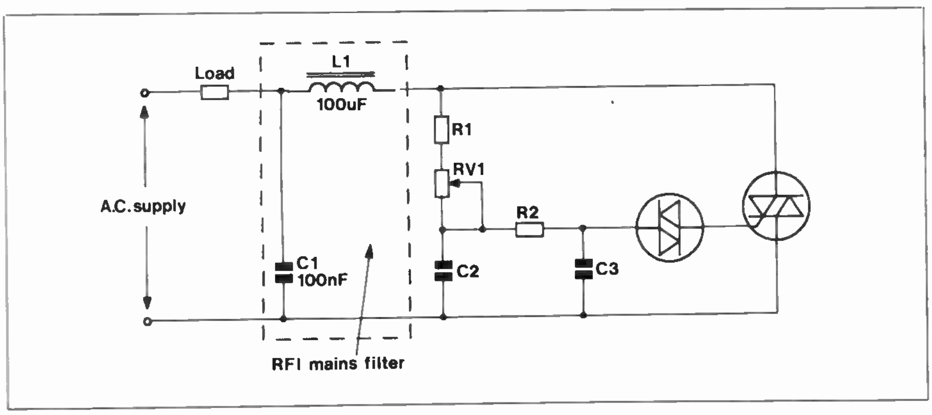


Figure 6. Double time-constant phase control circuit, with filter (L1 and C1) to eliminate RFI.

UJT Triggered Triac Automatic Lamp Controller

The purpose of this circuit, shown in Figure 8, is to provide a lamp that is automatically turned on at dusk and turned off again at sunrise. To do this it uses a CdS photo-cell (LDR) to control a UJT trigger circuit. A d.c. supply for the UJT circuit is derived from the mains by means of the half-wave circuit with shunt stabiliser, D1 and D2, the excess voltage being dropped across a wire wound resistor R1. This supply is smoothed by capacitor C1. The preset potentiometer RV1 forms a potential divider with the resistance of the LDR. In the dark the resistance of this cell is high so that it allows a voltage at least equal to the peak point voltage of the UJT to be developed across it; in the light, however, the LDR's resistance is small and the proportion of the d.c. supply that can be developed across it is not enough to trigger the UJT. Thus, as it gets darker the LDR resistance rises, as does the d.c. voltage across it until, eventually, it is sufficient to trigger the UJT which, in turn, triggers the triac, providing power to the lamp.

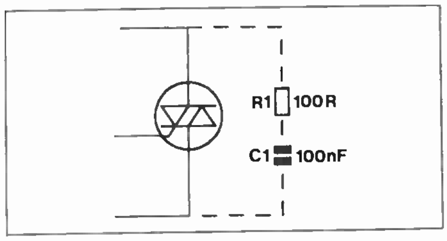


Figure 7. RC 'snubber' circuit to avoid accidental dv/dt triggering when the load is inductive.

The UJT operates, of course, as a free-running pulse oscillator so long as conditions allow it to be triggered; the triac is then automatically turned on again during every half-cycle of the supply. Since the frequency of the UJT oscillator is very much higher than the mains frequency, there is always a UJT trigger pulse available virtually at the start of every half-cycle of mains voltage. The value of light level at which the UJT triggers, so switching the light on, is adjusted by means of RV1. The position of the LDR should be chosen carefully so that it is not influenced either by the shadows cast by fixed objects or by people passing nearby during the lighter hours, or by bright lights, such as street lighting, during the darker hours.

Lamp Dimmer Circuits

It is quite popular nowadays to have some control over the brightness situations or simply to reduce light level at night for invalids or children. Since this merely means controlling the power to the lamp, it is an obvious candidate for thyristor control. Such units can be bought ready made but they are also very easy to make. Two possible circuits using, in one

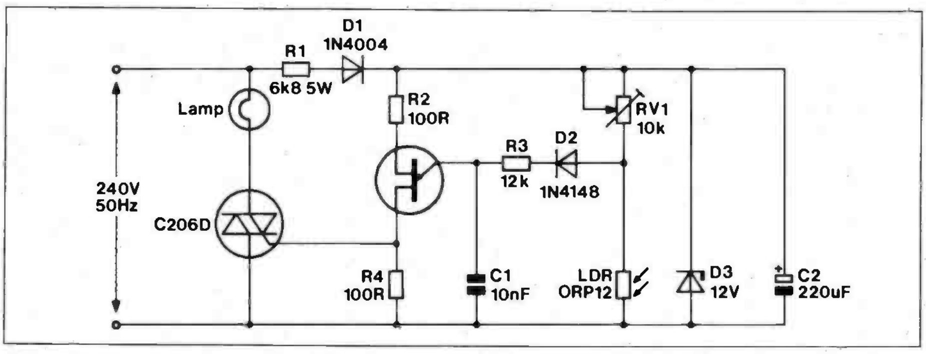


Figure 8. Circuit for an automatic lamp controller. The ORP12 photocell is used to control the UJT generator, triggering the triac on at dusk and allowing it to drop out at sunrise.

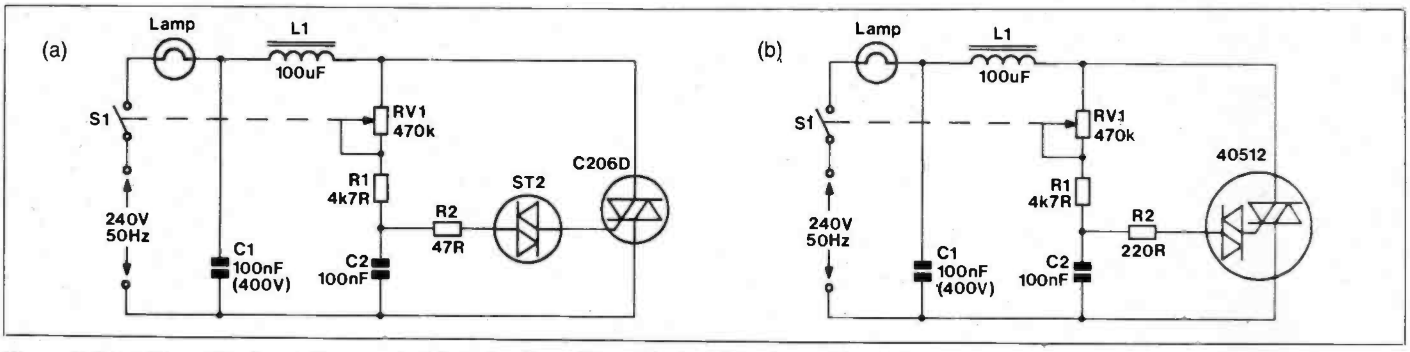


Figure 9. Two alternative lamp dimmer circuits, (a) using a diac and triac, (b) using a quadrac.

case, a diac/triac combination and, in the other case, a quadrac are shown in Figure 9. Both are single time constant phase control circuits with potentiometer control of power and an anti-RFI filter across the mains.

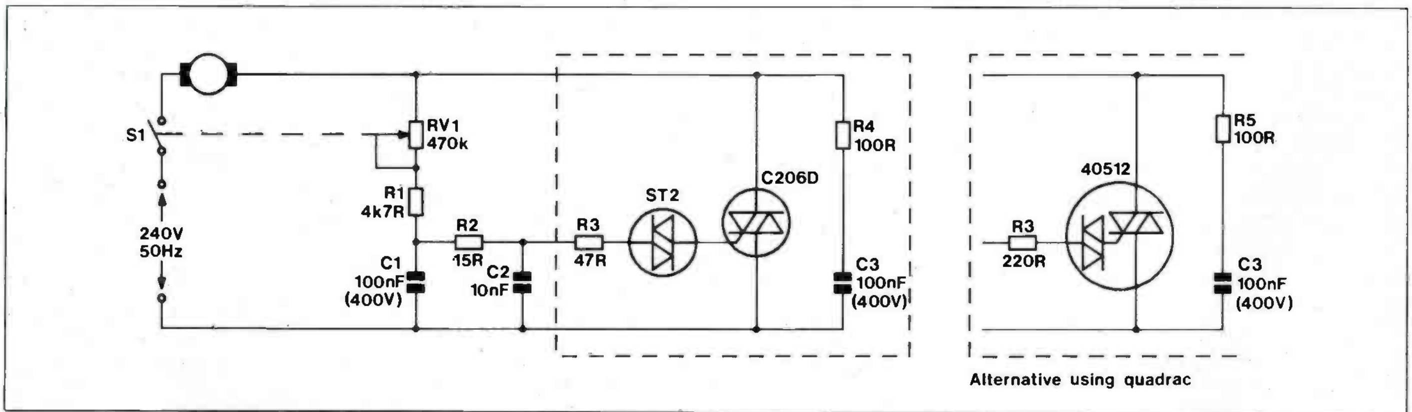


Figure 10. Two possible circuits for controlling the speed of a small universal motor. Either a diac/triac combination or a quadrac can be used.

Motor Speed Control Circuit

The universal motor, used in many domestic appliances, such as electric drills, food mixers, etc. is easily controlled by means of a thyristor circuit. There is no need to modify the appliance itself at all. The speed control unit can be housed in a tamper-proof box with a 13A mains socket mounted on it and a short flying lead with mains connector to plug into a ring mains socket. The appliance to be controlled – power drills are popular – is then plugged into the socket on the control box. Speed control is by means of a potentiometer and a very wide range of control is possible. A bypass switch can be included to allow full power to be applied directly to the appliance. Figure 10 shows two possible circuits again giving a choice between diac/triac and quadrac control. The ciruits are chosen to give as little backlash as possible and also include the RC snubber circuit mentioned previously because of the inductive nature of the load.

Zero Voltage Switching

The generation of radio-frequency interference (RFI) has already been mentioned, and its possible elimination by filtering discussed. An alternative approach to solving the problem is to control the power to the load, not by switching 'portions' of each cycle, but by turning the power on for so many whole cycles and off for so many whole cycles. For example, instead of switching power to the load halfway through every half-cycle (the worst possible time to switch anyway because this is the peak of the cycle), the power is switched on at the beginning of a cycle (the zero crossing point, hence the name), held for 'n' cycles, then switched off at the end of a cycle

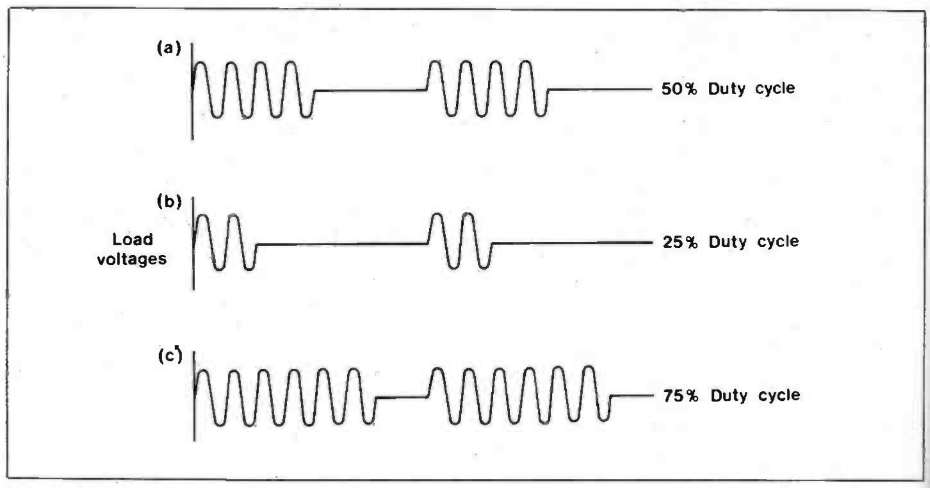


Figure 11. Waveforms to illustrate the principles of 'integral cycle control'. Power is controlled by the number of whole cycles supplied to the load, rather than by portions of cycles. As a result, load switching occurs when the supply voltage is zero.

(again the zero crossing point), held off for 'n' cycles, and this sequence repeated. This also gives half power in the load but the switching of power to the load will have occurred when the load voltage was zero, thus minimising or totally eliminating RFI production.

In general, power control can be obtained by switching a thyristor on for 'm' cycles and then off for 'n' cycles, as shown in Figure 11. Circuits to give this type of control can be made using discrete components but special ICs are available, the TDA 1024 being an example. A circuit utilising this IC is shown in Figure 12.

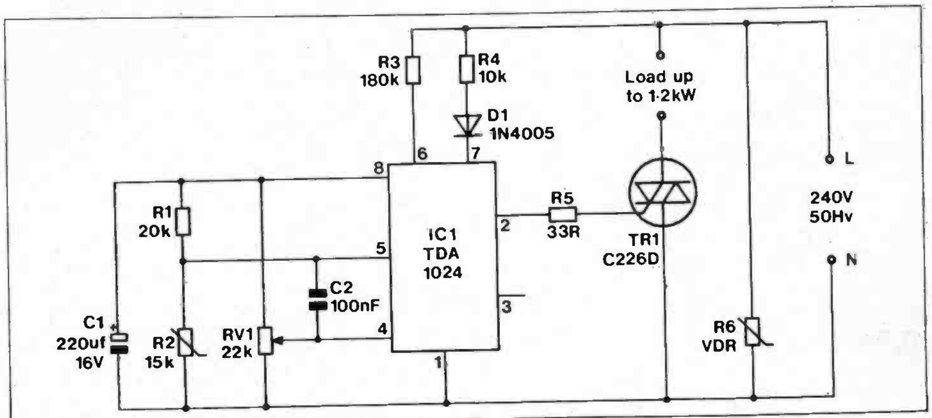


Figure 12. Practical circuit for integral cycle control using a readily available 'zero crossing detector IC'. A load up to 1.2kW can be controlled with this circuit. The C226D triac must be mounted on an adequate heat sink.

PUT or SCS?

To conclude this article we come back to the PUT, or Programmable Unijunction Transistor, which was mentioned briefly earlier. What does the reference to 'programmable' mean? The answer is quite simple and points to the uselessness of choosing terminology that is, at the very least, confusing. Programming in the usual sense doesn't come into it. A better word would be something like 'pre-settable'. This is because , what the PUT allows the user to do that can't be done with the conventional UJT is to predetermine the value of 'u', the intrinsic stand-off ratio. In the PUT circuit of Figure 13(a) a relaxation oscillator is shown in which two resistors, R2 and R3, are used to provide a potential divider for the anode gate of the PUT. In this mode the cathode gate is left open. It is these two external resistors that determine the value of 'u' rather than the internal interbase resistances of the conventional UJT. This allows us to make 'u' any fraction we like and to determine it with whatever accuracy we wish merely by the use of close tolerance, high stability resistors. The cathode of the PUT can be used to drive a thyristor gate directly; there is no need for a resistor from PUT cathode to 0V as there would be for Base 1 in the case of a UJT. The values for R1 and C1 can be whatever is needed to obtain the required frequency of oscillation. The circuit of Figure 13(b) shows a PUT circuit, using a readily obtainable device, the BRY39, that gives out a pair of antiphase pulses at a repetition frequency of 1kHz and requires only a 3V d.c. supply.

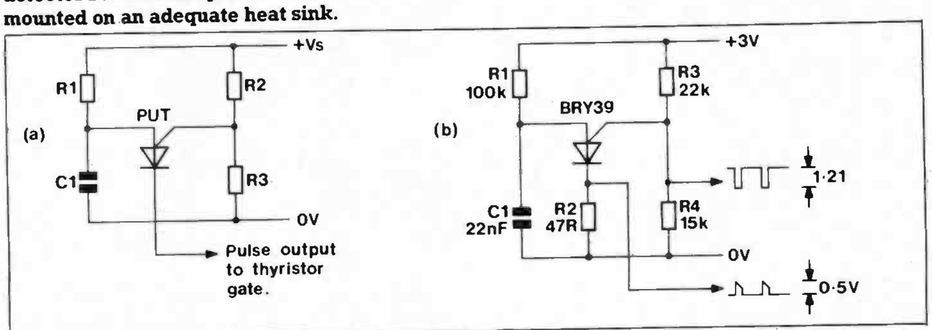


Figure 13. Using the PUT in the 'unijunction' mode, (a) general circuit for this mode, (b) a practical circuit for generating 1kHz pulses, needing a supply of only 3V. The value of 'u' is set by the values of R3 and R4 in the latter case [u = 15/(22 + 15) = 0.41].

The same device can also be used as the SCS of Figure 4(a). In this case, both the gates are used, having the functions described under the heading for that particular device. It is left to the reader to prove experimentally that this device will behave in the same way as a SCR but with the ability to be switched off by current pulses as well as on. A small lamp can, as in the earlier SCR experiments be used with, say, a 12V supply. The ratings of the BRY39 include a maximum anode to cathode voltage, either polarity, of 70V, with a mean current rating of 250mA and a peak current rating of 3A.

NEW MAPLIN SHOP IN LONDON

Reported by Robert Ball A.M.I.P.R.E.

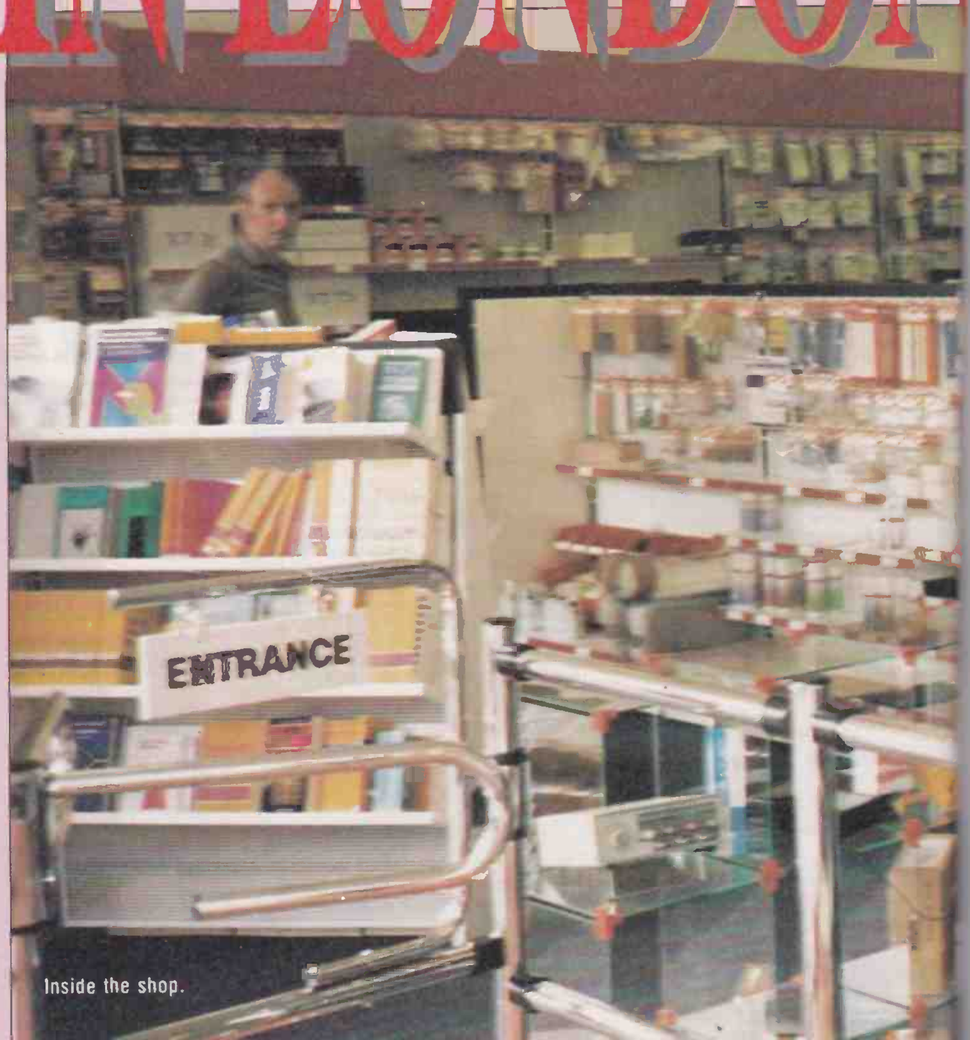
To complement the well established Maplin shop in Hammersmith, a brand new shop is now open at 146/148 Burnt Oak Broadway, Edgware in North London. This new shop, which was officially opened on 22nd June 1989, is already proving to be a big hit with both hobbyist and professional customers alike. The shop, decorated in red, black and white Maplin livery, is fully self service; the spacious layout giving the customer an opportunity to browse leisurely. Sales assistants are always on hand to give advice and help when needed. With Maplin prices, even the final visit to the check-out is a pleasant surprise on the pocket. Buses, London Underground and motorways are also in close proximity. If you are travelling by car you will have another surprise, albeit a nice one, as unusually for London, the new shop has excellent parking facilities. With an impressive, modern facade outside the shop, it is hard to miss.

Expanding

Opening the store, Patrick Horton who is the marketing director of the Middlesex Polytechnic, the third largest education centre in the country, welcomed the arrival of the Maplin shop to the locality. Middlesex Polytechnic are increasing their student base by 35% over the next few years, similarly, Maplin are expanding fast, with shops appearing right, left and centre. Patrick Horton commented that he was sure that his 700+ electronics students would be particularly interested in the new store. In reply, the joint managing director of Maplin, Roger Allen, pointed out that this was the ninth store to open country-wide. Certainly a far cry from the days when the first mail order operations began from his bedroom.

Here to Help!

The manager of the Edgware store is Laurence Saunders, he is a keen electronics hobbyist and has been working for Maplin since 1987. His interest in electronics originally started as a hobby whilst at school in Birmingham, he later started a BSc at Salford University. After leaving university Laurence was involved in voluntary work, and for five years as a residential social worker, helping people with mental handicaps. He eventually took another career move when he married, and joined the Maplin team at the Manchester shop as a sales assistant. Very quickly he climbed the ranks to assistant manager, later transferring to the Hammersmith branch as manager. Bringing us up to date, Laurence is the overall manager of both Edgware and



Inside the shop.

Left to right: Keith Evans (Shops Area Manager), Roger Allen (Director), Patrick Horton, Dave Snoad (Director), and Laurence Saunders (Shop Manager).

Hammersmith shops. Yet more responsibility is on the way; with his wife, Penny, expecting a baby in January!

I asked Laurence about the reactions of customers to the opening of the shop; "People have been saying 'Thank goodness your open!' and that Maplin products represent good value for money, things like that." I also asked about the sales assistants and he said that he has a good team that works well together. Laurence's team are Martin (assistant manager), Simon, Michael, Eamon and Mark.

Martin's interest in electronics was started off when he was younger; by a reel-to-reel tape recorder which went wrong. Since then his interest in electronics has gone hand in hand with that of audio, music and recording. Martin is an accomplished musician (grade 7 piano) and enjoys playing many keyboard instruments both old and new. In the past he has worked in hospital radio and as an audio visual technician. Martin first joined Maplin as a sales assistant at Hammersmith and quickly progressed to assistant manager.

Simon is a keen radio amateur and is a member of the RSGB and the IEEIE. He builds his own equipment for use in the VHF and UHF bands, he has a special interest in the SHF band as well. Simon comes from Doncaster and has BTEC ONC and HND qualifications in electrical, electronic and communications engineering. Apart from electronics and radio his interests include running and canoeing.

Michael has his background firmly rooted in music and started off constructing Maplin kits as a way to build up electronic effects for use with musical instruments. His main claim to fame is that of playing for the band 'Classix Nouveaux' and appearing twice on 'Top of the Pop's'. He plays quite a number of instruments including, saxophone, lead guitar and fret-less bass guitar.

Eamon was at Norwich University where he studied computer engineering and electronic systems. His interest in electronics was sparked off by computers, whilst studying for his 'A' levels. His interests include music, sport, reading and, of course, electronics!

Mark is currently waiting for his City and Guilds 224 Electronics Servicing exam results to come through. His interest in electronics started by taking things to bits (and then having to put them back together again!). His hobbies include radio controlled cars, computers, tennis and pool.

Getting There

If you live/work in or near the London Edgware area, then you will find the new Maplin shop convenient for all your electronic component and project requirements. Access by London underground is via the Northern Line (Burnt Oak) or via the Jubilee Line (Queensbury). Bus services past the door are the 32, 114 and 141 and access by road is quick and easy from the M1, A41, A5, M25 and A1. For service, stock and value that is hard to beat, why not pay a visit to the best electronics store around! Where you will be assured of a warm friendly welcome.

Maplin Electronics, 146/148 Burnt Oak Broadway, Edgware, London.
Tel: 01-951-0969
Open:
Monday to Saturday, 9:00 am to 5:30 pm

COMPUTERS IN THE REAL WORLD

Part 2 by Graham Dixey *C.Eng., M.I.E.E.*

If a computer is to interact with the 'real world', it has to be capable of exchanging data with it. This means that it will be accepting some form of data input, processing it in some way, and then providing some form of output that is related to this input. Some of the possible 'peripheral' devices that might be exchanging data with the computer were discussed in a general way in Part One. In this second part we shall consider some of the devices that commonly provide data inputs. For the moment disk drives will be excluded as they will be dealt with in more detail later. Much of the present discussion will concern a device known by the general term of 'transducer'. These are of particular importance in a way that the average computer user rarely has to contend with – since they are used to derive suitable signals from the natural environment. Hence they are largely concerned with the application of computers in controlling a wide variety of physical processes rather than in the field of office automation, which is already well covered by the computing press.

However, there is one input device that is worth looking at briefly, at least from the hardware point of view, since it is the one that most people will have some practical acquaintance with. The device in question is the keyboard.

Most keyboards have two identifiable parts, the 'keyswitch array' and the 'encoder'. The keyswitches are usually simple single-pole single-throw types, with normally open contacts. The function of the encoder is to convert the simple switch closure into a complete ASCII code for that particular key. The output from the keyboard, generated in this way, is usually in parallel form, though a serial output can easily be obtained if desired. Other features of the encoder include the suppression of switch contact bounce, the ability to handle the case when more than one key is pressed at a time and the generation of a pulse, usually known as the 'keyboard strobe', which is output whenever a key is pressed and signals this salient fact to other circuits. A further feature of the encoder is that it allows a key to have several different functions by combining it with the use of the 'shift' or 'control' keys.

The ASCII code (American Standard Code for Information Interchange) mentioned above is actually a 7-bit code but the eighth bit of the byte is often used for 'parity', which is a method of error checking. Thus, if a particular 7-bit code has an odd number of '1s', making the parity bit a 'one' then produces 'even parity' (an even number of 1s in the byte); conversely, if the parity bit has a value that produces an odd number of ones in the byte, then the result is 'odd parity'.

The most popular key layout is the standard QWERTY arrangement, so called because these are the first six in the upper left area of the alphabetic keys. To make keyboards 'user friendly' the keys should be of a certain minimum size, be arranged on 3/4" centres and have some sort of tactile feedback for the user, usually a result of positive travel and a sensation experienced through the finger tips that data really has been entered. Zero travel, membrane-type keyboards have, in the past, been something of a failure. Staggered, sloped or dished arrangements are common on computer keyboards. These factors are mentioned because they influence enormously the ease with which a human can interact with a computer, especially over prolonged time periods.

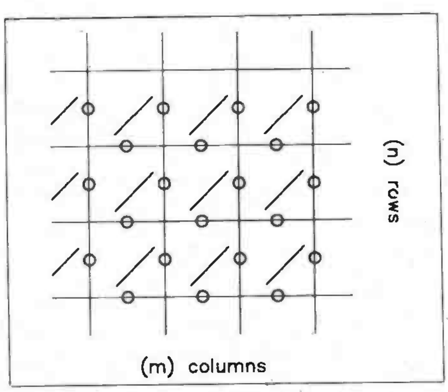


Figure 1. Part of an m × n keyboard matrix, showing positions of keyswitches on the row/column intersections.

Rollover and lockout are ways of preventing incorrect codes from being generated when more than one key is pressed at a time. In 'n-key lockout' the first key down generates the strobe, the others do nothing. Although very simple it has the obvious disadvantage that key presses can be missed completely. This snag is avoided with '2-key rollover' in which, if a second key is down at the same time, logic is used to allow the keypress of the second key to be recognised soon after that of the first key down. There is also 'n-key rollover' in which the codes for any number of keys down are successively stored and recognised in turn. It is, however, rather too complex for most applications.

Encoder Circuits

As already stated the function of the encoder is to convert the single pole key press into the equivalent ASCII code for that key. There are various types of encoder but one that is of particular interest is the 'scanning encoder'. In this type the keys are arranged in a matrix. For example, a 64-key keyboard could be arranged on an 8 x 8 matrix. This is not the physical arrangement of keys, of course; they are laid out on the QWERTY system as already discussed. The matrix refers to the way in which the 'below board' wiring is connected to the switches. The wiring is laid out as '8 columns x 8 rows' with one switch across each column/row intersection (see Figure 1). Thus, pressing any key produces a unique short-circuit at a given intersection. A key press is identified by a scanning process that interrogates each key in turn through an oscillator and a decoder/selector circuit. The elements of a keyboard based on these principles is shown in block diagram form in Figure 2.

In operation a gated oscillator, running at a frequency of about 50kHz, clocks a 6-bit counter. The top three bits of the counter are decoded to a 1-of-8 sequence that places a logic 1 on each of the eight column lines in turn. The bottom three bits of the counter drive a 1-of-8 data selector that interrogates each of the eight rows in sequence. When a key is pressed the coincidence of the active column and the row where the key press has occurred is used to stop the oscillator while the code for the key is generated; a keyboard strobe is also produced. For the circuit shown in Figure 2 the actual code generated is simply the pattern of binary digits that appears on the seven output lines at the instant that the counter is 'on hold'. This figure also includes extra gating to make use of the shift and control keys to generate extra codes.

Any desired code can be generated, e.g. the ASCII code referred to, by storing the codes in a ROM and using the binary outputs from the scanned keyboard, not as the actual codes themselves, but as addresses in the ROM where the actual codes are found. The block diagram of Figure 3. shows the arrangement for a scanning keyboard which uses codes stored in a ROM, each output code from the ROM being held in a set of latches before being passed to the computer.

Transducers

A transducer, in the most general sense, is merely a device that is able to convert one form of energy into another. There are a number of everyday examples of this conversion process. The loudspeaker is one, in which an electrical input is converted into an acoustic output. The microphone, to quote another example, performs the opposite process, of producing an electrical signal from an acoustic input. In general, since a computer requires an electrical input, of a very specific kind, the types of transducers that will interest us will be those that take some physical quantity and derive an equivalent electrical signal from it.

It is worth considering some examples of physical quantities that we might wish to convert in this way, and consider how such conversion might be carried out. Their relevance to computer control is also worth investigation.

Examples of such physical quantities are: heat, light, weight, force, linear displacement, angular displacement, stress in mechanical structures, fluid velocity, etc.

Transducers for all of these quantities exist and may be classified as being either 'active' or 'passive' types. To make the distinction clear, an active transducer generates electrical energy directly – an electromagnetic microphone is an example, since it uses the principle of electromagnetic induction. By contrast, the passive transducer requires an electrical supply which it then 'modifies' in some way so as to develop its output. A capacitor microphone is an example of a passive transducer which needs to be fed with a d.c. supply; the moving plate of the capacitor then modulates this d.c. supply with the acoustic signal.

Transducers for Temperature Measurement and Control

An industrial oven, furnace or similar environment can be readily controlled by a microcomputer. Transducers exist that allow a voltage that is proportional to temperature to be obtained. Two possible types are the thermocouple and the resistance thermometer.

Thermocouples are temperature-sensitive devices that operate on the Seebeck effect. When a circuit is formed of two dissimilar metals (Figure 4) and heat is applied to one of the two junctions, a voltage or current is developed in the circuit

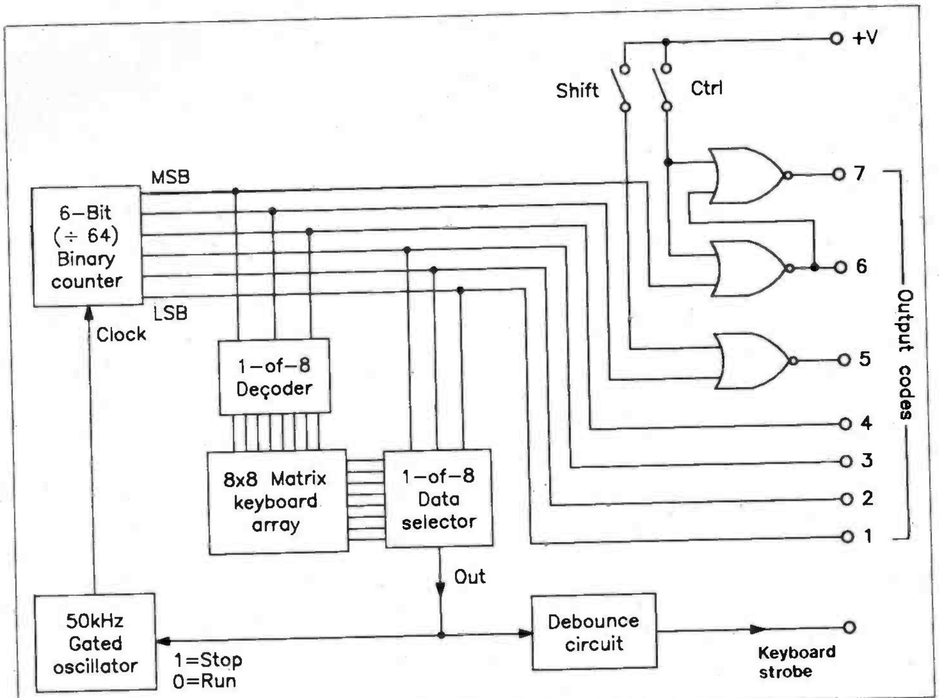


Figure 2. A scanned keyboard.

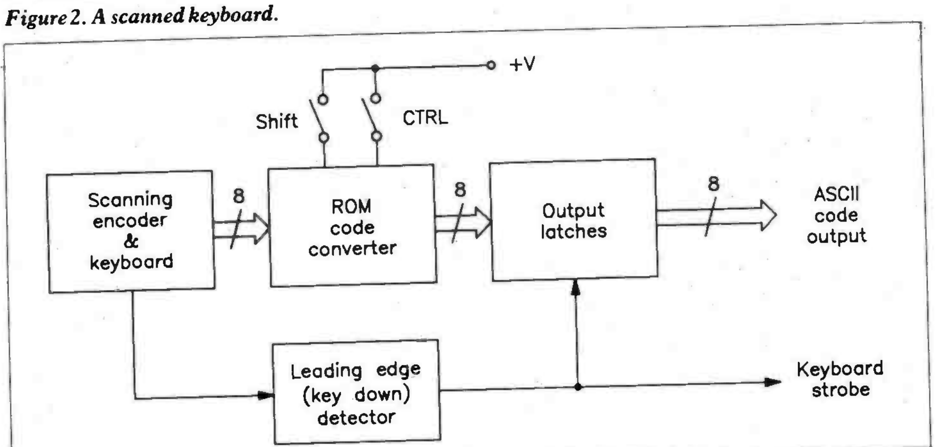


Figure 3. A scanned keyboard with ROM to store the ASCII codes.

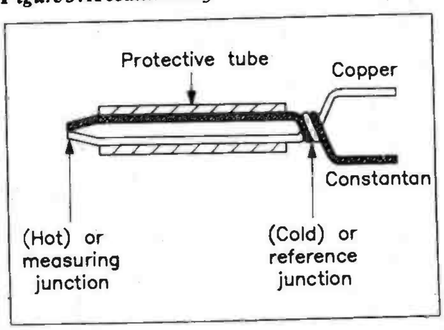


Figure 4. Essential construction of a copper/constantan thermocouple.

that is proportional to the difference in temperature between the two junctions. Examples of metal combinations that are commonly used are: copper/constantan and iron/constantan. The useful temperature range for these is −250°C to +400°C and −200°C to +850°C respectively. Since these devices generate electricity directly they are, of course, active transducers.

The resistance thermometer operates on the principle that metals change their electrical resistance with changes in temperature. Resistance thermometers are particularly useful where high sensitivity is required. They are used to measure temperatures from approximately −75°C to +550°C. Platinum or nickel are the materials commonly used.

An inexpensive temperature transducer of the resistance thermometer type is the thermistor. It is made from sintered mixtures of metal oxides and has semiconductor characteristics. It has a negative temperature coefficient, which means that an increase in temperature causes a reduction in the resistance of the device. The operating temperature is fairly limited (−100°C to +400°C). Typical values are a resistance of 5000 ohms at 0°C and 100 ohms at 150°C. One problem with thermistors is the extreme non-linearity of their characteristics but they are very sensitive indeed and, in the bead variety, very fast acting.

Both types of resistance thermometer are passive devices and are generally used in a Wheatstone bridge circuit in order to develop a voltage related to the resistance change – the bridge 'out-of-balance' voltage. Since the actual transducer may be at a distance from the bridge itself in a practical situation, the possibly long connecting wires would become a fixed part of the transducer total resistance; to avoid this drawback, a modified form of bridge, called the Mueller bridge, is used instead. This is shown in Figure 5.

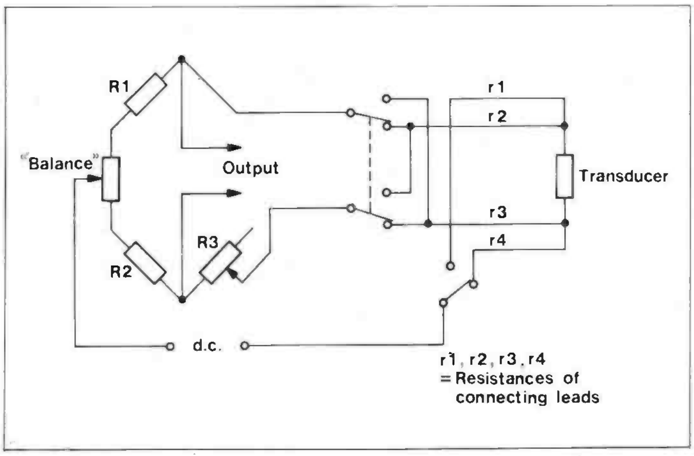


Figure 5. The Mueller bridge, used when long connecting leads are involved.

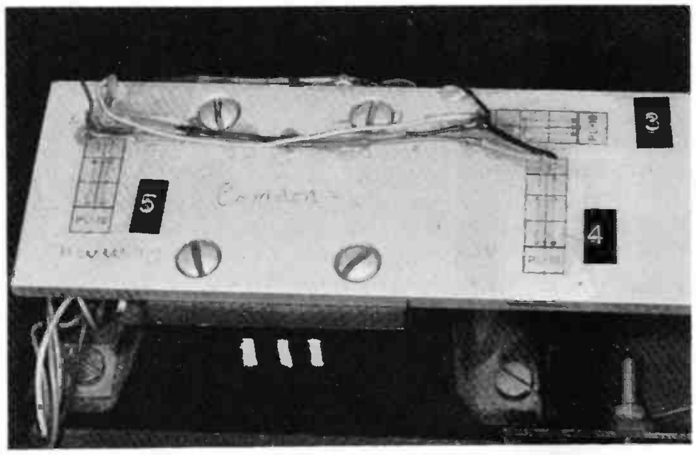


Photo 2. Strain gauges cemented to a beam. Numbers 3 and 4 are the 'active' gauges; number 5 is a dummy for compensating the bridge.

Transducers for Force and Displacement

The Strain Gauge

The strain gauge works on the principle that the resistance of a conductor depends upon its physical dimensions. Thus, if something influences any of these dimensions, a change in resistance will occur. This change can be detected and measured in a bridge circuit. These devices can be made from various metals, alloys or semiconductors. In practice they take the form of a very fine conductor network that may be unbonded (that is free in space) or bonded to a fine foil which is cemented to the member in which the force is to be measured, see Photo 1.

Typical resistance values are 120, 350 and 1000 ohms. It is quite usual to place two similar strain gauges in opposite arms of the bridge, one being merely a 'dummy' to give a reference to which the other, under stress, is referred, see Photo 2.

The Linear Variable Differential Transformer (LVDT)

This is a transducer that can be used to measure linear displacement directly and force with a modification, see Photo 3. The schematic construction is shown in Figure 6. A single primary winding is surrounded by two identical secondary windings. A magnetic core moves down the centre of the coil arrangement and will influence the

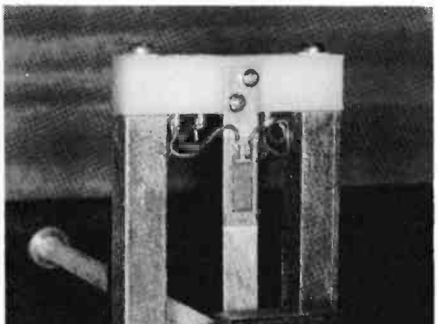


Photo 1. A single strain gauge attached to a member under test in loading jig.

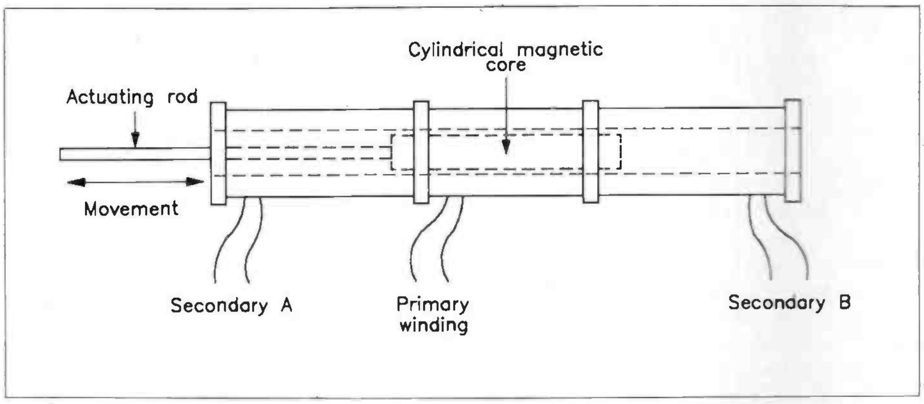


Figure 6. Basic construction of a Linear Variable Differential Transformer (L.V.D.T.)

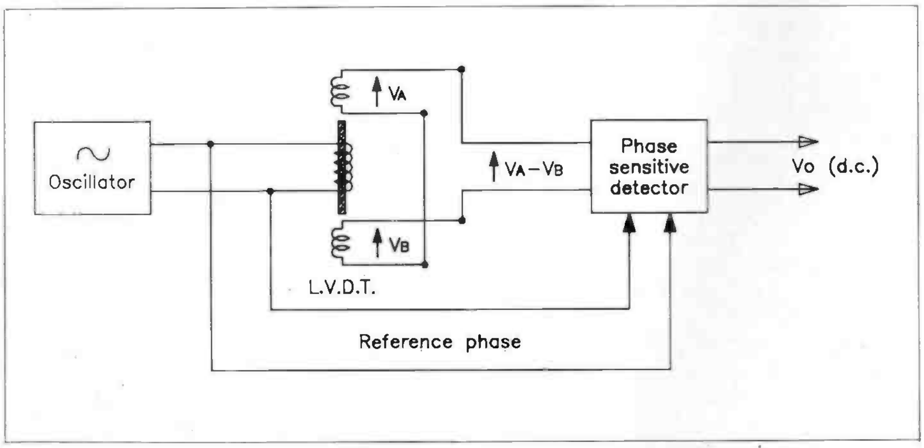


Figure 7. A polarity-sensitive output, proportional to linear displacement, can be obtained from a L.V.D.T. using a 'phase sensitive detector'.

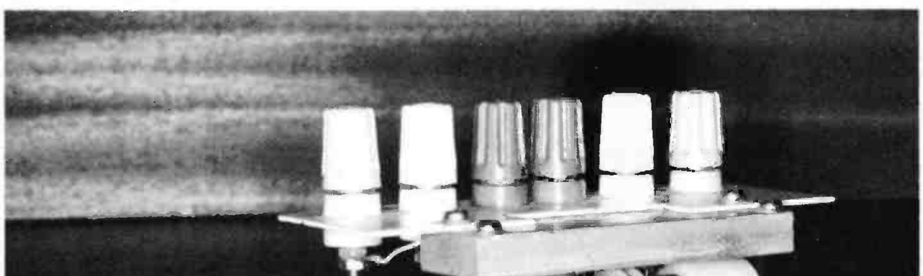


Photo 3. Example of a linear variable differential transformer (L.V.D.T.). The 'displacement' input is via the spring-loaded shaft.

amount of electromagnetic coupling between the primary winding and each secondary winding, according to its position relative to them. If exactly centrally placed the coupling will be the same to both secondaries and the induced voltages will be equal and opposite. The net output will be zero. Movement in either direction will cause one or other secondary voltage to be larger than the other; there will be a net output.

Not only will the magnitude of the displacement be sensed but the direction also, since there will be a phase reversal as the null point is passed through. The a.c. output can be passed to a 'phase sensitive detector' which will rectify it and produce a d.c. output that is either positive or negative (or zero) depending upon the direction of movement of the core, see Figure 7.

Optical Transducers

The Photo-conductive Cell

One of the most useful of optical transducers is the Cadmium Sulphide (CdS) photo-conductive cell. This is a clear plastic case containing a resistance element whose value depends upon the strength of the light falling on it. Enormous variations in resistance are possible, from 'tens of kilohms' down to a few hundred ohms being typical. The coefficient of resistance change with light level is a negative one but is sufficiently constant to give reasonable linearity between the two quantities.

Optically Coupled Isolators

An optical coupler (Figure 8) consists of a gallium arsenide (GAs) infrared emitting diode and a silicon photo transistor mounted in close proximity but electrically isolated. Such a device has the

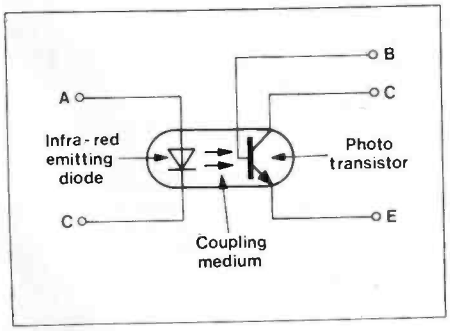


Figure 8. The optically-coupled isolator (opto-coupler or opto-isolator).

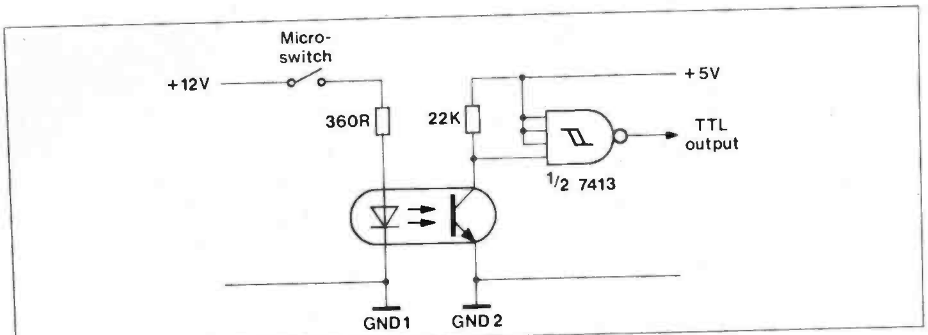


Figure 10. Using an opto-isolator to couple digital data between two circuits.

advantages of very high electrical isolation between input and output, good linearity between input and output currents, compatibility with TTL logic circuits, high speed, long life, good mechanical strength and a high current transfer ratio. It can be used as a simple switch or in a linear mode.

In the switching mode the photo transistor operates under saturated conditions and switches between the on and off states. In certain industrial applications of digital equipment it is necessary to interface between sensors, such as micro-switches, that are situated in electrically noisy environments, and the control equipment itself. The circuit of Figure 9 shows how this can be done with an optical coupler, so avoiding the pickup of extraneous noise.

The optical coupler can also be used to transmit digital data between two digital systems where there is a substantial difference in the earth line potentials. This is shown in Figure 10. The data rate is normally limited to about 125-150kHz.

Optical couplers also exist as multi packages, e.g. quad isolators, with high gain, high speed circuitry and with triacs as the output switched element.

In the linear mode the linear relationship between diode forward current and photo transistor current is used. In this mode the input current may be a function of some other variable, e.g. resistance change, and the isolator is used purely to obtain linear coupling with a high degree of electrical isolation.

Two other ways of using optical transducers are shown in Figure 11. In (a) an optical coupler is arranged so that a slotted disc passes between the transmitting and receiving sections. Each time the slot appears in the optical path an output pulse is generated.

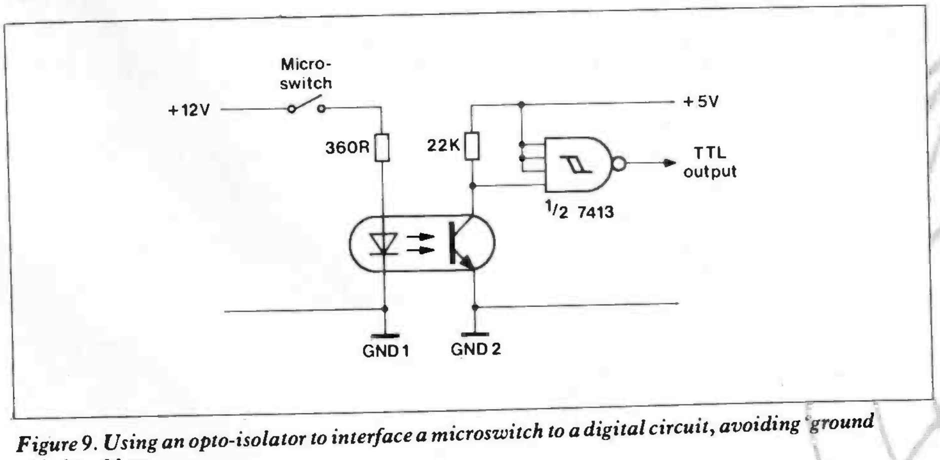


Figure 9. Using an opto-isolator to interface a microswitch to a digital circuit, avoiding 'ground noise' problems.

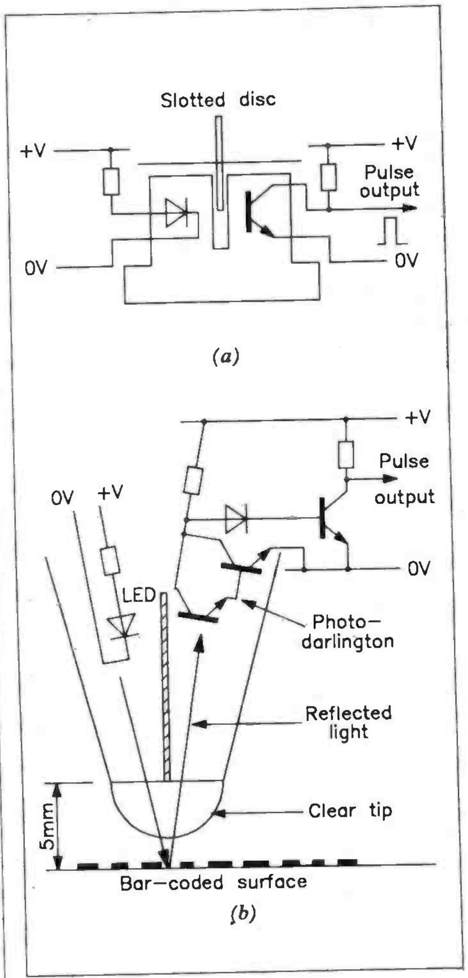


Figure 11. (a) Principle of optical coupling applied to the generation of pulses by a rotating, slotted disc (e.g. to measure engine speed), (b) Using a LED and a photo-Darlington amplifier to read bar codes.

Figure 11 (b) shows a reflective transducer which will generate a serial digital output as it moves over a succession of black and white bars (e.g. bar codes). The distance of 5mm is optimum and can be kept constant by a clear plastic lens at the tip, which contacts the surface. For high gain a photo-Darlington pair is used to drive a BC108 output stage.

The Photo-diode as an Optical Sensor

The advantage of a photodiode over a CdS cell is its very much faster response, measured in microseconds or even nanoseconds. The silicon photo-diode is normally operated with a reverse bias so that, in the dark, the diode current is extremely small, a few tens of nano-amps only. An increasing light intensity causes a nearly linear increase in diode current. The

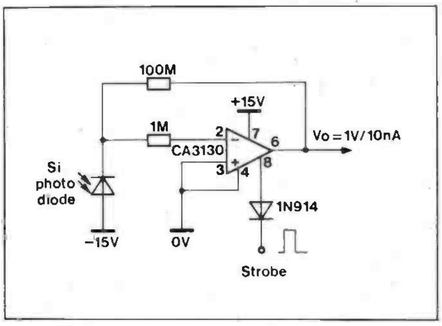


Figure 12. The silicon photo-diode used to measure light level. Good linearity exists between output voltage and ambient light level. The response is fast too.

circuit shown in Figure 12 gives an output voltage of 1V/10nA of diode current and allows the output to be read by a microcomputer by strobing pin 8 via the 1N914 diode. The low diode currents involved necessitate the use of a CMOS op-amp and correspondingly high values of the input and feedback resistors.

Potentiometric Transducers

Potentiometers, whether linear or rotary, are able to give an output voltage which is a function of the wiper position. Thus, they are useful in providing a 'position dependent voltage'. Various applications may spring to mind, including position feedback in control systems, liquid level measurement (by using a float and a suitable mechanical linkage to drive the wiper) and input demands from front panel controls. The accuracy of the derived signal depends upon the 'linearity' of the potentiometer track (resistance variation with change of wiper position) and resolution (the number of turns of wire used to make up the track – the finer the wire, the more fragile but the better the resolution), see Photo 4.

There are a variety of other transducers, for example for measuring flow rate of liquids, for measuring pressure, for measuring the pH factor of various liquids, humidity, density, etc. They all have one thing in common; they all take 'natural' quantities as their input and produce an analogue output. However, there is one type of transducer that is capable of producing a digital output directly. That is the digital shaft encoder.

The Digital Shaft Encoder

This is the only true transducer that is capable of giving a parallel digital output. It comprises a circular disc on which a series of radial patterns of light and dark areas, each representing a binary number, is applied, to be read by a number of sensing heads, see Photo 5. Each of these binary numbers corresponds to a unique angular position of the disc. Thus, since an 8-bit number can take any of 256 different values, an 8-bit disc (i.e. having eight annular tracks) can identify 256 separate angles, each being 360/256 = 1.4° apart. In practice the resolution usually needs to be better than this. The sensing heads may be of the contact, magnetic or optical type.

In the contact type, brushes bear on the annular tracks, either making electrical contact or not according to whether a binary 1 or binary 0 is being read. This type is subject to the usual problems of such contact arrangements, namely physical wear, dirt, friction, arcing, etc.

The magnetic type offers an improvement by using a magnetically coated disc on which the binary patterns have been pre-recorded. Readout is effected by small toroidally wound heads.

Best of all is the optical type of sensing head. This gives the best accuracy and imposes no mechanical loading on the disc. The disc is usually photo-etched so that it has clear and opaque regions to represent the binary values. The light from a suitable source will then either pass through the disc or not, this being detected by means of photo-cells. A typical trackwidth is about 12 microns (a micron is a millionth part of a metre) and 14-bit optical encoders are common. With this number of bits the resolution is 214 = 16,384 angular intervals, each of value 360/16384 = 0.022°.

The binary pattern used on disc encoders does not follow a pure binary sequence, since if it did large angular errors would occur whenever the sensors stopped on the junction of two segments. This is because the sense heads always tend to read the TOTAL number of logical 1 bits and form the output from this. Thus, a sense head on the junction of 0111 (7) and 1000 (8) would actually read 1111 (15), giving a substantial error. However, if a code is used in which successive binary numbers differ by only a single bit, the error is very small. Such a code is called a Gray code. In this code decimal 7 is 0100 and decimal 8 is 1100. Sensors reading the junction of these two numbers will now read 1100, thus simply rounding up to the larger value of the two.

This survey of transducers has necessarily been brief but perhaps has given some idea of the wide variety that are obviously available. The next stage is to consider what to do with their outputs before their data can be processed by the computer. In almost all cases the output is in analogue form, and usually it is of quite a small magnitude. What has to be considered next is how to 'condition' this analogue signal and how to convert it to digital form so that it is acceptable to a microcomputer. This will be the topic of Part Three in this series.

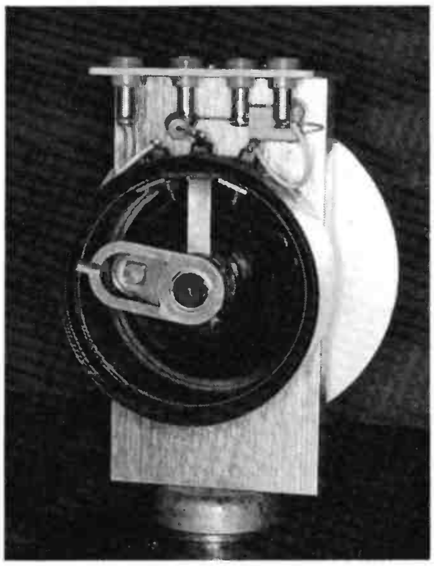


Photo 4. Example of large wirewound (rotary) potentiometric transducer.

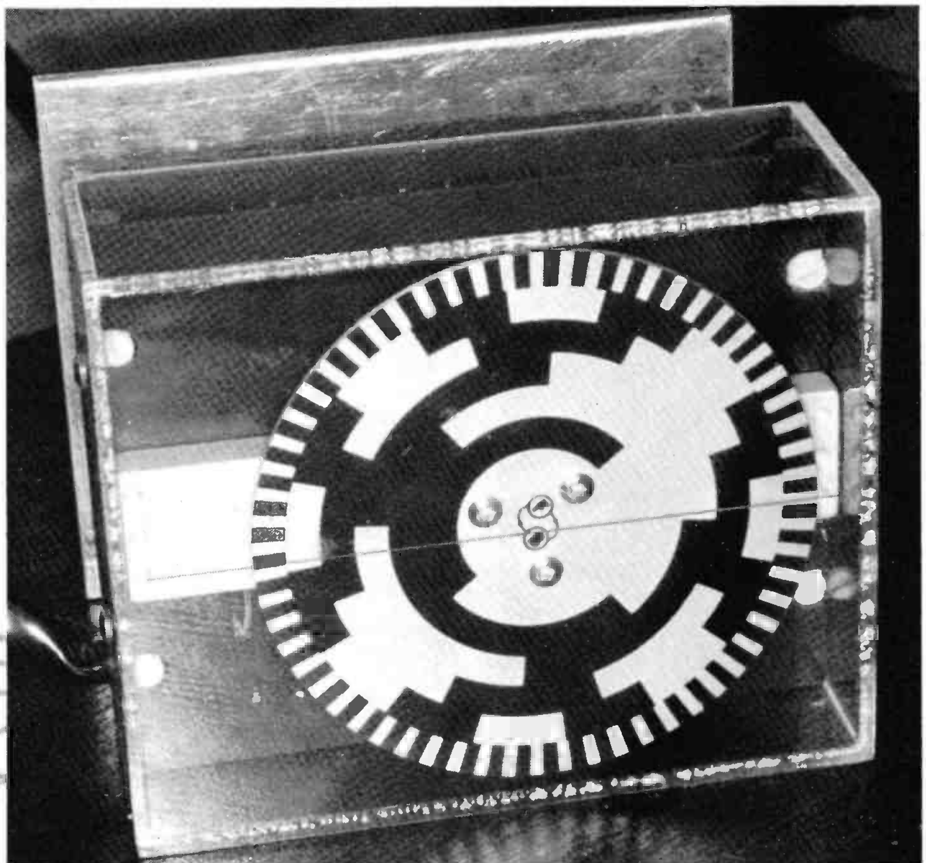


Photo 5. An example of a digital shaft encoder, in this case a 5-bit type, as is evident from the five concentric rings.

Air your views!

A readers forum for your views and comments. If you want to contribute, write to the Editor, 'Electronics - The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.

In Which The Virtues of a Magazine Subscription are Extolled

Dear Sir,
I believe that a little while ago, you asked what we would like to see in 'Electronics'. Well, I have a suggestion as the result of getting myself into a little muddle. I'd love to see an article on capacitors! What is the difference between the different types? What are the principle uses for the different types? How do they differ in construction (physically)? Any tips or things not to do?
I. Wicker, Fakenham, Norfolk.

The good new is that an article covering all your questions was published in issue 20 of the Maplin Magazine. The bad news is that this issue is now out of print. The moral is to ensure you have every issue of this wonderful magazine and this can be achieved by applying now for a subscription and renewing it when necessary. That you may not have been born when issue 20 was published is scarcely an excuse. Greasing the editor's palm with silver (though gold in preference please – Ed.) can sometimes elict a photocopy of out of print articles, but in this case a photocopy is already winging its way to you free of charge. Our generosity knows no bounds.

Hearing The Good News

Dear Sir,
I have just received my copy of the April-May issue of 'Electronics', and, like a number of other readers I would like to congratulate you on its new format. It is good to look at and good to read! The church which I attend is considering installing the inductive loop hearing aid system, and I am wondering if it would be possible for one of your technical chappies to write an article explaining exactly how this – very useful I am told – system works. I am interested both as a (retired) electronics engineer, and as one who has hearing problems.
H. V. Kirby, Hayling Island, Hants.

Pleased to hear you like our new look mag. The theory of induction loops is a bit specialised for a general article, but the principle is that a loop of wire (the aerial) is taken around the area in which the signal is to be picked up. The systems use very low frequencies and most church hearing aid systems use 0 to 16kHz. A licence is not needed to operate, but the transmitter must be type-approved by the D.T.I. The relevant specifications can be found in MPT1337 and MPT1370 (available free of charge if you send an A4 size s.a.e. to the D.T.I., Radiocommunications Division, Room 605, Waterloo Bridge House, Waterloo Road, London SE1 8UA) and the operational requirements are in BS6083 Part 4:1981 available at main libraries. The receiver circuit can be very simple requiring mainly a coil and amplifier. The more saintly members of your congregation will find their haloes are excellent aerials at these frequencies, but we recommend they turn surly and kick a few nearby shins during thunderstorms.

Air Band Views

Dear Sir,
In the June/July edition of 'Electronics – The Maplin Magazine', I was interested in the article on the Marine Band receiver in the Exploring Radio series. Can you tell me if there is a Maplin kit for the Air Band used by civil aircraft (108 – 140 MHz)? If there is not an actual kit would it be possible to modify another design? I must say I enjoy the new magazine and look forward to reading each edition.
R. Burkett. Surrey.

Sorry to say that we don't have a kit for those who wish to listen in to this most interesting band. It's certainly a good idea for a future project if we can find a way of keeping the alignment simple.

Snap Decision

Dear Sir,
On opening the packet containing my 'Britannica Book of the Year 1989' I found the enclosed circular, and thought that the picture at the bottom was familiar. Yes! It is almost, but not quite, the same picture as used on your front cover of the June/July edition. So does your photographer also work for Encyclopaedia Britannica, or have they borrowed one of your photographs?
A. E. Robinson, Sale.

We asked our intrepid photographer H. Snapper, if he'd been selling pics to 'Encyclopaedia Britannica'. "I'ave ter make a livin' don' I?" said Happy. In future we shall be using the Editor's son's Polaroid so that copies cannot be made. Thus you will be able to see at last that we all have orange eyes.

Polythene Knockers

Dear Editor,
Since the introduction of polythene envelopes for despatching 'Electronics' magazine to subscribers, I have experienced the following difficulties of non-delivery and late delivery. In fact, I have been able to see the magazine at W. H. Smith ten days before I received my copy. May I suggest that the label is too small and gets obscured by the printed matter on the envelope, or by falling to the bottom of the envelope and lodging under the magazine, which may be causing delay in the sorting office. I shall be interested to know if my case is a one off, or if other subscribers are experiencing the same difficulties. As a subscriber for the past ten years I have only encountered this difficulty since the use of these polythene envelopes. Hoping that my suggestion will be of some assistance in the future despatch of your excellent magazine.
R. Richards, Taunton, Somerset.

The truth is that the dear old Post Office has a problem competing with the efficiency of the magazine distribution system in the UK. This is the system that gets your daily newspaper to you usually before the postman arrives, within a few hours of it being printed. We have asked our printer to ensure that the first copies off the press are the ones to be posted, but it is still quite likely that W.H. Smith will get their copies on sale quicker than the Post Office can deliver to you on some occasions. We will talk to the Post Office to see if the address label size is a problem for them.

Remote Review

Dear Editor,
In the projects and modules section of your 1989 catalogue I discovered that a new project, the I.R. Remote Switch, appeared without a previous review in any of your magazines. I expected to see a review in forthcoming magazines but to my surprise four magazines later no review has appeared. Can you please tell me why a review has not appeared because without it, constructors have no information on the kit therefore they are reluctant to buy it. Will there be a review in a future issue?
P. Adams, Bath, Avon.

Sorry it took us so long to get round to printing the details of the project – as you will have seen, it appeared in the last issue. The editor has so many good things for each issue that its difficult to fit everything in (he says). Actually I think he just forgot it till he saw your letter! (No I didn't – Ed.) Isn't it annoying how editors always have the final (word – Ed).

BT Kills Phone Projects

Dear Sir,
As a logical progression from your series of articles on loudspeakers and telephones, I – and probably many others – would find it very useful if you could include a project/article on the construction of an answerphone. There are some solenoid operated twin cassette decks currently available on the amateur market which could form the basis for the project. The outcome would be a worthwhile exercise with a practical outcome (aren't they all)?
R. J. Snashall, Hants.

Unfortunately the outcome of such a project would be the heavy hand of the law on our collar. Only type-approved equipment can be connected to the telephone lines though there is not the slightest technical justification for this. So although we would love to produce some telephone projects, they would have to state that once built, it would be illegal to connect them to a telephone line. The outcome would be that only the recklessly criminal amongst you would build them. And the outcome of this outcome is that we wouldn't sell many outcomes.

Demodulator Depletion

Dear Editor,
Having just recently bought the June/July 1989 copy of the Maplin Magazine, I was very much interested in (Chris Barlow's) FSK Demodulator Series. Having ordered the Demodulator kit I am told that it is out of stock at the moment – is it possible in future articles to list a complete set of P.C. boards for the projects so that people like myself can order all the boards at once, as having to wait 2 to 3 months for your magazine to show up on the book racks means that the project gets forgotten about for a while. I do not know how long I will have to wait for my order, which I am sure will be delivered shortly, it would be nice to be able to order complete kits.
C. R. Gibb, Dundee.

The demand for this project proved to be greater than we anticipated and we ran out within a few weeks. Sorry you had to wait – we were out of stock for three weeks at the beginning of July – but as you will see now you have your kit, it is complete. Each part in the series is a complete project in its own right. The only way we could make it more complete would be to make it into a module, but that would probably upset de module 'aters.

Ace Says Joker

Dear Sir,
The other day I noticed, when reading a Maplin Magazine from 36 years ago, a minor spelling mistake. No, not really, just joking. I was wondering if all your Maplin boffins could come up with some simple infra-red, ultrasonic remote controls. I personally would like to see an ultrasonic mains-relay, battery-powered remote control to run my hi-fi from the mains. Also, I would like to see some audio projects, not another amplifier, probably a graphic equalizer. I can't understand the circuit diagram for the graphic equalizer in the catalogue. Or I would like to see a L.E.D. 20, 30 or 100 bargraph for audio levels for speaker systems, the Watt Watcher isn't enough. Mind you, I appreciate the work you have done, and the catalogue is ace.
Ian Quigley, Penzance, Cornwall.

Maplin boffins! You must be joking. Our designers wouldn't know an infra-red beam if they saw one. As to your other suggestions I can only say that I personally would like to see Maria Whittaker in the (stick to the point! – Ed). What a wonderful idea.

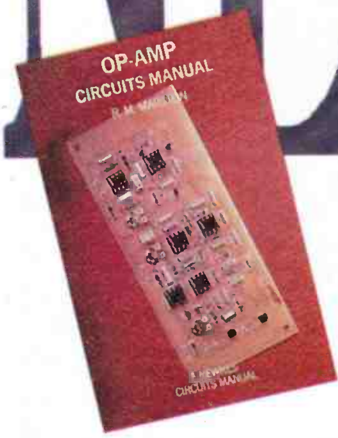
The Life and Times of Fred

Dear Sir,
A letter in praise of your up/down timer, Maplin No. FS11M, or as I call him, Fred. I found Fred tucked away in the miscellaneous section of your catalogue, and being a concerned fellow I sent my £7.95 away and awaited Fred's arrival with baited breath. And so it came to pass that in time the postman delivered Fred with the touch of a midwife through my letter box. I unpacked Fred and thanks to your staff he was unharmed, as I may say are all your packages to me, but I digress. Fred and I hit it off at once, he would get me up each morning and would not let me oversleep no matter how I tried and things were going so well. But one morning I came in only to find him sunbathing under my bedside lamp, he was so hot his display had gone. I put him in the fridge to cool off and some twenty minutes later Fred was peeping at me to let him out, all was well and he was totally unharmed. About three months later, I was telling him what time to wake me the following morning when Fred leapt out of my hand straight into a pint of water. Under he went, it is a pity it is not olympic selection year, with a fizz and pop – I thought once again his display had gone and this was the end, nothing electronic could survive this, so with a heavy heart I laid Fred to rest on my bedside table and reached for my Maplin 1989 Catalogue to order son of Fred but my heart was not in it. Some three days later I looked at Fred and I could not believe it, Fred was well and telling the time. So no matter what I do, Fred seems to survive. Hear's to more like Fred.
Mike Scully, Lancs.

*What a heart-warming story. It brings a lump to your throat. Actually the up-down timer I bought was struck by lightening and still worked. Then I accidentally dropped it in some sulphuric acid that was passing by, but I tipped it out and it **still** worked. Then it got run over by a steam roller. I took it back to a Maplin shop and the bloke in there said the battery was flat.*

If any readers have other thoughts, ideas, comments and suggestions, please write in!

NEW BOOKS



Op-Amp Circuits Manual

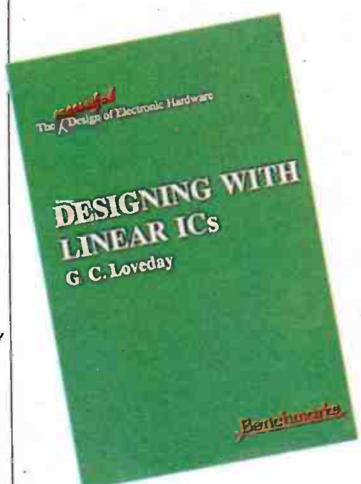
by R. M. Marston

One of the most popular and versatile 'building blocks' of our time is the operational amplifier or 'op-amp'. The 'standard' type is generally the most familiar, but you will also find described in this book the less well-known 'Norton' and OTA types. In addition a total of over 300 practical circuits, with diagrams and tables, are provided for the practical design engineer, technician and experimenter alike. It will be of equal interest to the electronics student and the amateur, and is written in a down-to-earth, non-mathematical and very readable style.
211 pages. 138 x 215mm, illustrated.
Order As WS47B (Op-amp ccts manual) Price £12.95NV

An Intoduction to Amateur Radio

by I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the century. It encompasses a wide variety of subjects from the historical to the latest technology, and from operating to construction. In fact there is always some aspect of the hobby to interest people.
This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used over and over. Topics include the basic aspect of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.
160 pages, 112 x 176mm, illustrated.
Order As WS50E (Intro Amtr Radio) Price £3.50NV



Designing with Linear IC's

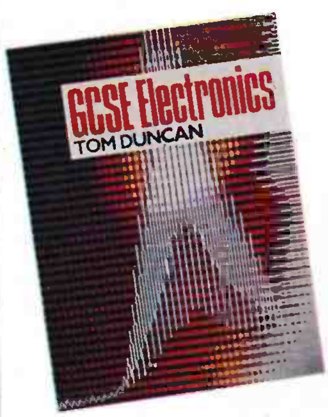
by G. C. Loveday

Covers the design techniques for analogue and linear circuits. Although they may now seem to form a relatively small part of modern electronics systems, the 'in-thing' being of course digital, nevertheless there are still many requirements for designs using linear circuits. In this book the special problems encountered in the type of work are discussed, and detail circuit solutions to specific tasks are used as examples. Beginning with the general techniques and design methods, the book goes on to describe CAD tools, testing strategies and specific problem areas in linear design work.
180 pages, 137 x 212mm, illustrated.
Order As WS49D (Design Lin ICs) Price £8.75NV

Computers and Music

by R. A. Penfold

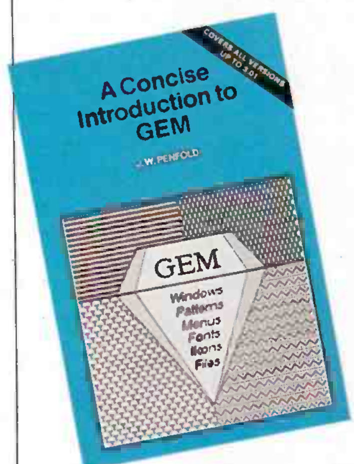
Computers are playing an increasingly important part in the world of music, and the days when computerised music was strictly for the few rare fanatics are now long gone. In the past, computer-based music systems have tended to be either horrendously expensive or very crude or both. But now prices are becoming ever more affordable while the potential of the equipment is always increasing. Consequently then more and more musicians are being tempted into the unfamiliar territory of computer music systems.
Hence this book, a sort of beginners guide to computers from the musicians' point of view, who will almost certainly be put off by the jargon and terminology bandied about by computer buffs. As such it will help you learn the basics of computing, running applications programs, wiring up a MIDI system and using it to good effect, in fact just about everything you need to know about hardware and programs, with no previous knowledge of computing needed or assumed.
182 pages, 137 x 215mm, illustrated.
Order As WS52G (Comp & Music) Price £7.95NV



GCSE Electronics

by Tom Duncan

Electronics is the most vital and rapidly growing area of modern technology, with major effects on everyday life, commerce and all types of industry. This comprehensive textbook, written by an author world-renowned for his books on physics and electronics. The book: Is fully up to date with current developments in the subject. Is designed to meet the requirements of all GCSE Electronics and the Electronics component of Technology courses. Develops the subject logically from first principles through to electronics systems, with reinforcement questions (and answers) throughout. Has useful references for practical aspects of the course. Contains check lists of learning objectives and additional banks of questions (with answers and explanations) at core and further levels, so that students can monitor their progress throughout the course.
180 pages, 210 x 280mm, illustrated.
Order As WS42V (GCSE Electronics) Price £6.50NV



A Concise Introduction to GEM

J. W. Penfold

If you have a computer which uses GEM, this book is designed to help you get the most from it. Though much of GEM is straightforward, you will find those parts which are not explained here. Not just written as an introduction for new users, it has also been structured to provide a convenient, compact source of reference for more experience users, and serves to refresh the finer points for anyone who has not used GEM for sometime.
The book describes GEM and its capabilities, how it can be used for the housekeeping of both hard and floppy disk files, how to configure and run applications from the GEM desktop to best advantage. All versions of GEM up to release 3.01 and including the versions supplied with the Amstrad PC and Atari ST machines are covered, and all the GEM menus, graphics and other special features available to users within GEM applications programs.
80 pages, 130 x 195mm, illustrated.
Order As WS51F (Cons Intro GEM) Price £2.95NV

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